Applications of Remote Sensing Data and a Regional Forecast System for Improving Flash Flood and Fire-Weather Forecasts in Southern California

NASA/SENH (NAG5-13248)

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Project Goals

- Build *a regional weather and streamflow prediction system* for improving the operational flash flood and fire-weather forecasts at the NWSO-LA/Oxnard and the Ventura County Watershed Protection District (VCWPD) for southern California.
  - The weather and streamflow prediction system will be based on one-way coupling of an NWP model to be operated at the NWSO-Los Angeles/Oxnard and a streamflow model developed and operated by Ventura County Watershed Protection District (VCWPD).
  - A regional NWP model driven by the operational NCEP forecast data can produce forecasts at finer spatial resolutions than the operational NCEP forecasts. This can improve QPF in So. Cal as precipitation in So. Cal is strongly affected by local orography.
- Examine the applicability of remote sensing data for improving flash flood and fire-weather forecasts in Southern California.
  - Incorporate the *precipitable water vapor* (PWV) values measured at the southern California Integrated GPS Network (SCIGN) sites for improving the QPF for the So. Cal region by improving the accuracy of the initial atmospheric water vapor fields for a regional NWP model.
  - Investigate the *impact of surface memory*, for example regional-scale SSTs and soil moisture, on *extended-range water cycle forecasts* for SWUS and California.

Motivation

- Flash floods and wild fires are the two leading weather-related natural disasters in southern California.
  - Extreme contrast in seasonal precipitation creates high fire hazard in late summer and early fall.
  - Of the 10 highest 24-hr rainfall totals in California, all 10 have occurred in southern California.
  - Volatile oils released from burning vegetation form hydrophobic upper soil layers, which, in conjunction with steep terrain slopes, enhances the chance of flooding during heavy rainfall events.
- Accurate QPF capability is crucial for reducing flood damages.
  - Sub-10km scale QPF desired by NWSO and VCWPD for hydrologic forecasts is not usually available.
  - Regional NWP system operated by individual NWSOs can help frontline forecasters and local emergency response agencies.
- One of the keys for short-term QPF is accurate initial atmospheric water vapor fields for a regional NWP model.
  - Atmospheric water vapor data for the southern California region suffers from a lack of observations over the eastern Pacific.
  - Remote sensing can provide additional water vapor data for a local forecast system.

Wildfires usually occur in remote areas.

The Curve Fire seen from the Mt. Wilson Observatory. 16:55 1 Sept, 2002.

Occasionally they can be too close!

The 2003 Simi Valley fire seen from Jinwon's backyard, day (Left) and night (Right).

Then, there are winter storms

Newly created canyons near Lake Castaic after January 2005 Southern California storms.

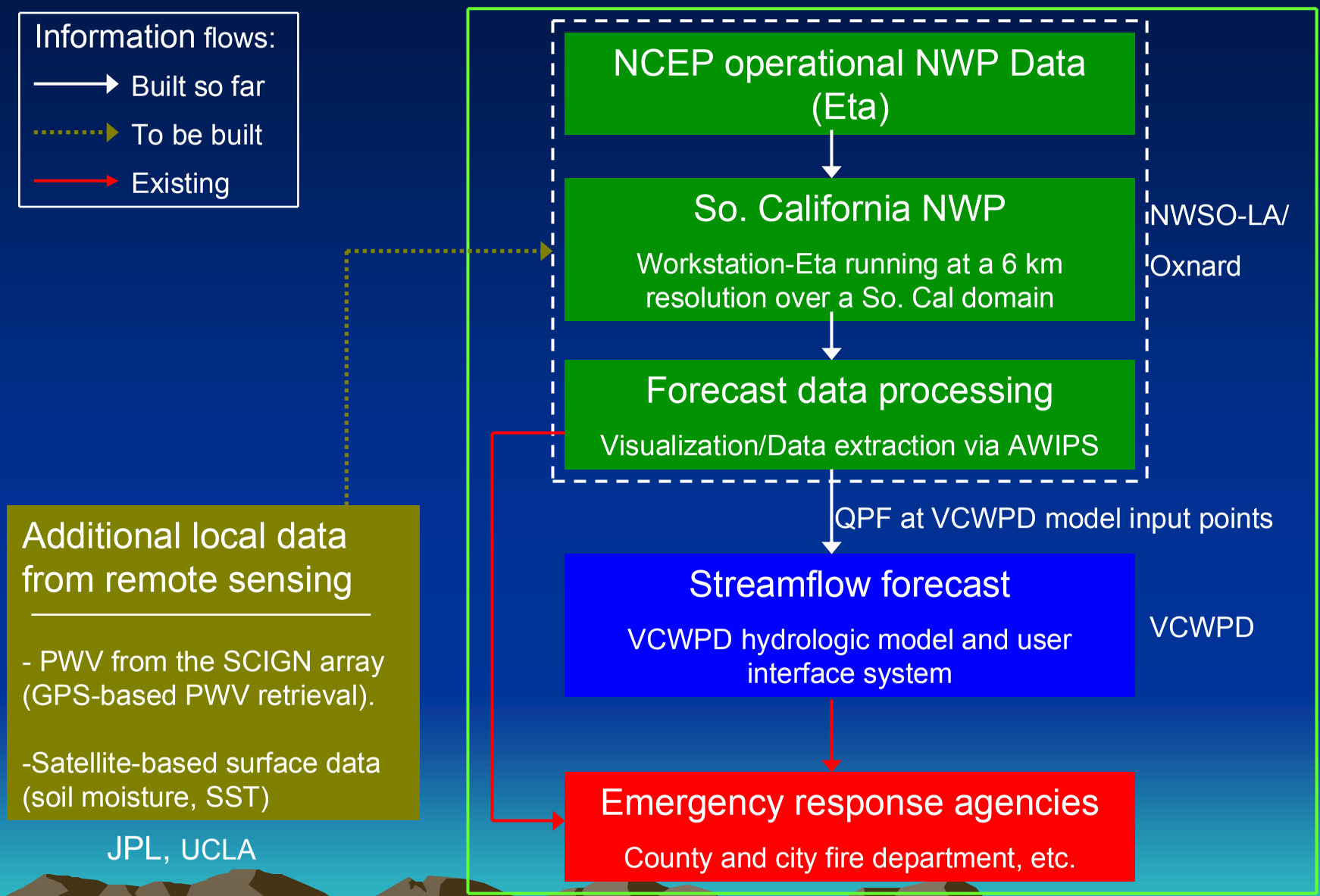
Project progress so far

- The Integrated Regional Forecast System (IRFS) infrastructure
- PWV retrieval at the SCIGN GPS receiver sites
- Case studies for examining the impact of the PWV retrieved at the SCIGN sites on the QPF in southern California.
- Seasonal water cycle study
  - The impact of atmospheric aerosols on surface insolation and spring snowmelt in California.
  - The impact of the Gulf of California SST forcing on the warm season rainfall in the North American Monsoon region.

The Integrated Regional Forecast System (IRFS) for So. California

- The NCEP Workstation-Eta model has been successfully integrated within the NSWO-LA/Oxnard AWIPS environment.
  - The So. Cal NWP system has been operational since the summer 2004.
  - The NWSO-LA/Oxnard generates four 72-hr forecasts each day.
- The data link between the WS-Eta QPF and the VCWPD streamflow forecast model is quasi-automated via anonymous ftp and script files, however, it includes some manual operations.
  - Beta-testing of the system is underway since late 2004.
  - The major difficulties in fully automating the data flows between the NSWO and the VCWPD is associated with the computer security restrictions at the corresponding agencies. This has not been a major problem as both the NWSO and VCWPD are operational institutions (24-hour human link is available).
  - After the initial testing stage, the two agencies plan to work more efficiently to overcome institutional barrier.
- *We have successfully established strong personal connection between the two agencies.*

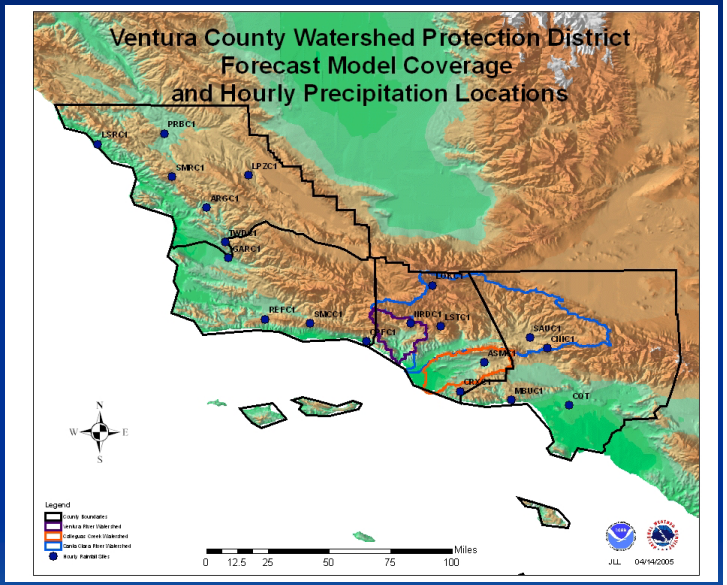
The outline of the Integrated Regional Forecast System

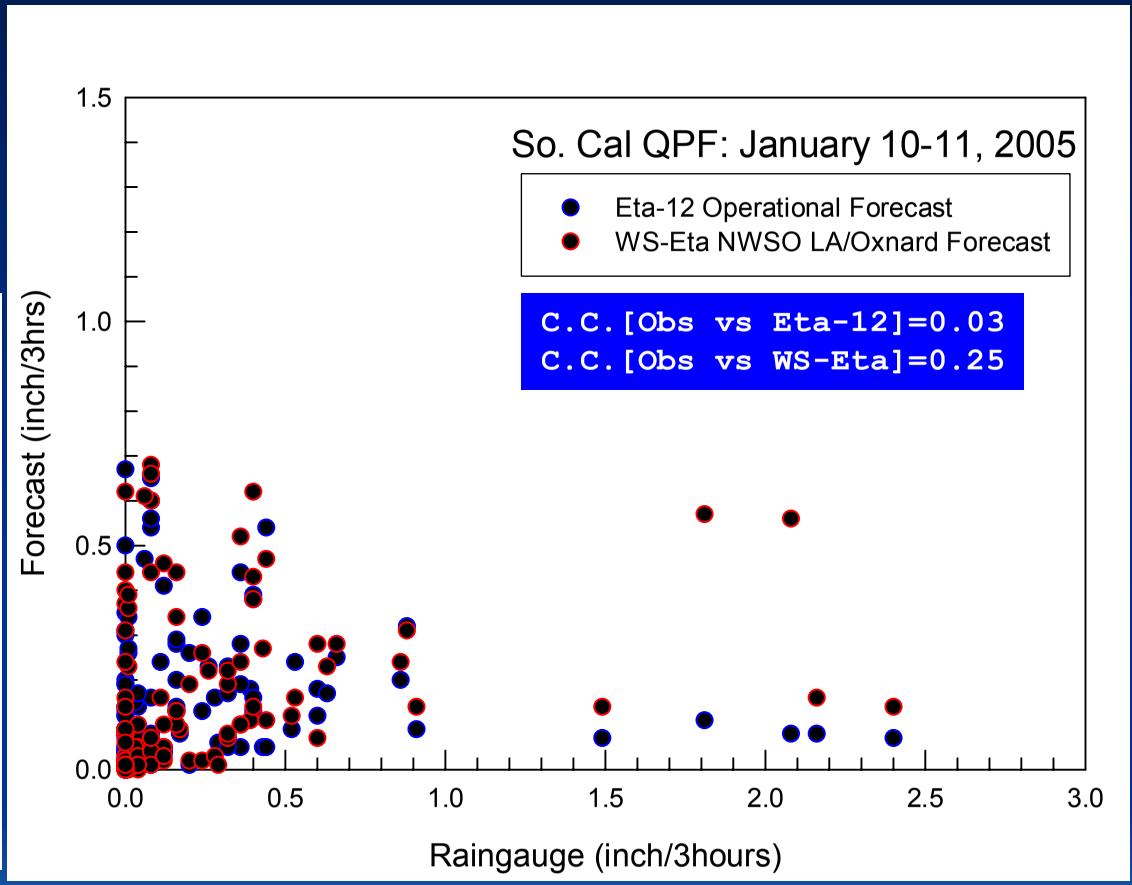

Information flows:
Built so far
To be built
Existing
NCEP operational NWP Data (Eta)
So. California NWP
Workstation-Eta running at a 6 km resolution over a So. Cal domain
NWSO-LA/ Oxnard
Forecast data processing
Visualization/Data extraction via AWIPS
QPF at VCWPD model input points
Streamflow forecast
VCWPD hydrologic model and user interface system
VCWPD
Emergency response agencies
County and city fire department, etc.
Additional local data from remote sensing
- PWV from the SCIGN array (GPS-based PWV retrieval).
-Satellite-based surface data (soil moisture, SST)
JPL, UCLA
Experimental component
Operational component

The 3-HR So. Cal QPFs at the NWSO-LA/Oxnard based on the WS-Eta

Blue: NCEP operational Eta-12; Red: NWSO-LA/Oxnard WS-Eta

The VCWPD raingauge locations used for evaluating the WS-Eta rainfall forecasts

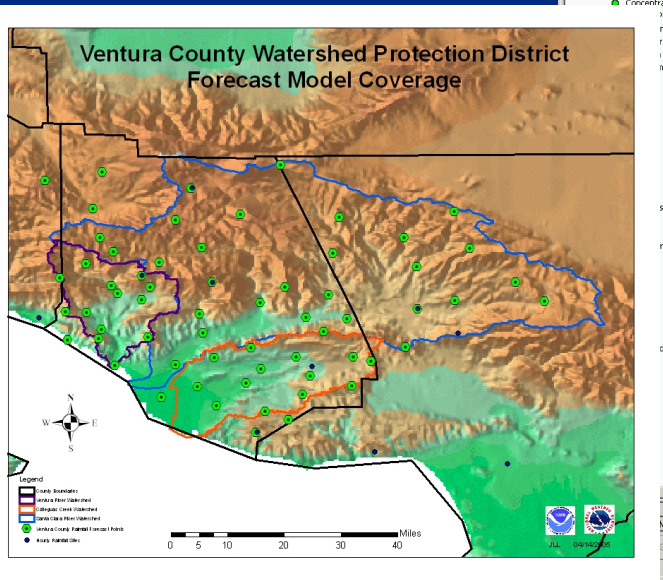


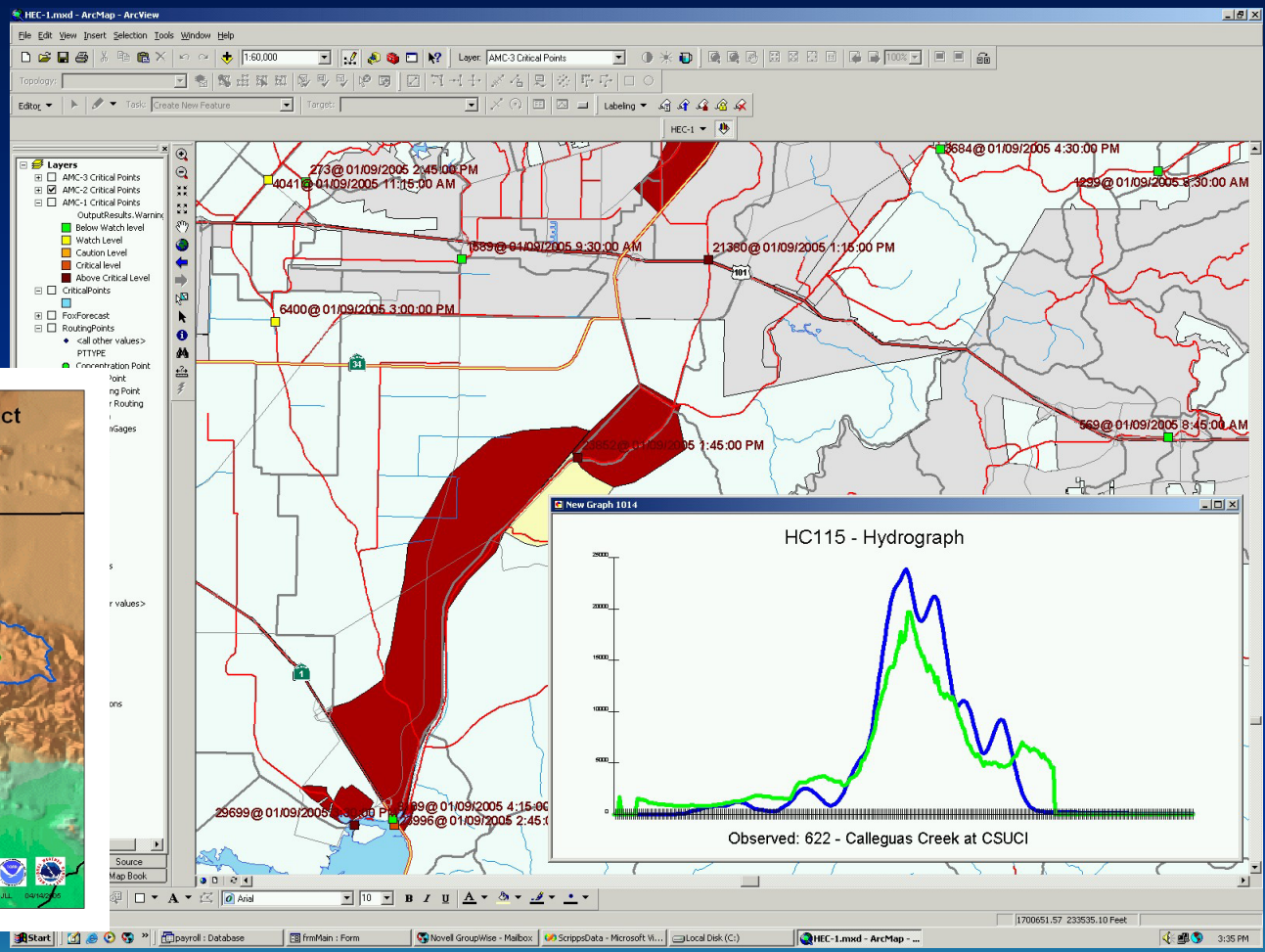


- Both QPFs from NCEP and NWSO-LA/Oxnard underestimate rainfall, but
- WS-Eta improves overall QPF, especially in heavy rainfall cases.
- The regional QPFs from the WS-Eta are more closely correlated with observations.

The streamflow forecast produced by the VCWPD system

The QPF input points for the VCWPD streamflow forecast model





- The streamflow forecast for Calleguas Creek on January 9, 2005
  Blue: Forecast; Green: Observation
- The red areas red indicate the regions that have the potential to be flooded

The VCWPD rainfall & flowrate summary

VCWPD RAINFALL & FLOWRATE SUMMARY TABLE
ISSUED: 01/08/2005 11:15 BY: SH

Quantitative Precipitation Forecast - Fox Weather, LLC
ued: 01/08/2005 07:59:02

Basin or Area	Interval rainfall(inches) Every 3 hour(s), beginning: mm dd hh									totl DAY1 sat	totl DAY2 sun	Out-look 3-5day mon-wed
	3to 6	6to 9	9to 12	12to 15	15to 18	18to 21	21to 0	0to 3	3to 6			
Upr Ventura	0.01	0.11	0.12	0.28	1.33	0.20	0.32	0.26	0.01	2.37	2.04	2.86
Ventura	0.01	0.08	0.08	0.17	0.78	0.12	0.23	0.19	0.01	1.47	1.24	1.82
Oxnard	0.01	0.07	0.07	0.16	0.71	0.11	0.21	0.17	0.01	1.34	1.12	1.66
Sespe	0.01	0.10	0.11	0.26	1.24	0.18	0.30	0.24	0.01	2.20	1.89	2.66
Calleguas	0.01	0.06	0.07	0.14	0.66	0.10	0.19	0.15	0.01	1.22	1.11	1.94
Fagan	0.01	0.08	0.09	0.19	0.86	0.13	0.24	0.19	0.01	1.60	1.40	1.93
Lockwd Vly	0.01	0.09	0.10	0.24	1.14	0.17	0.28	0.22	0.01	2.03	1.75	2.45

QUANTITATIVE PRECIPITATION FORECAST - NATIONAL WEATHER SERVICE, OXNARD CA
ISSUED: NATIONAL WEATHER SERVICE LOS ANGELES/OXNARD CA

	04-07	07-10	10-13	13-16	16-22	22-04
FAGAN CANYON	0.5	0.5	0.6	0.8	1.7	1.1
MATILIJA DAM	0.5	0.5	0.7	0.9	1.8	0.8
VENTURA COUNTY GOVT CENTER	0.3	0.3	0.4	0.7	1.7	1.1
CIRCLE X RANCH	0.3	0.3	0.5	0.9	2.0	1.7

AMOUNTS GREATER THAN ZERO BUT LESS THAN A TENTH OF A INCH ARE SHOWN AS LGT

Storm Rainfall Summary Last 5 Days

ea	01/08 Snc 8	01/08 8-8	01/07 8-8	01/06 8-8	01/05 8-8	Last 7Days total	Seaon Total snc 10/01
sar Pk(RanchFire)(20):	0.98	2.91	0.43	0.24	0.16	4.92	28.82
La Conchita Area (694):	0.12	0.35	0.51	0.00	0.00	2.99	14.29
Upper Ventura R (29):	0.91	2.28	0.35	0.39	0.35	7.17	35.71
Hopper(Piru Fire) (662):	0.31	2.76	0.35	0.35	0.28	6.06	23.23
Ventura-Govt Cntr (110):	0.00	1.14	0.59	0.00	0.00	3.50	13.90
Sespe (Wolf Fire) (40):	0.87	3.19	0.31	0.12	0.00	4.65	21.02
Santa Paula Creek (634):	0.20	1.54	0.39	0.00	0.00	4.21	21.61
Tripas (Simi Fire)(640):	0.30	1.21	0.32	0.00	0.01	4.63	18.24
South Mtn(Simi Fire)(7):	0.08	1.42	0.43	0.00	0.00	4.06	13.50

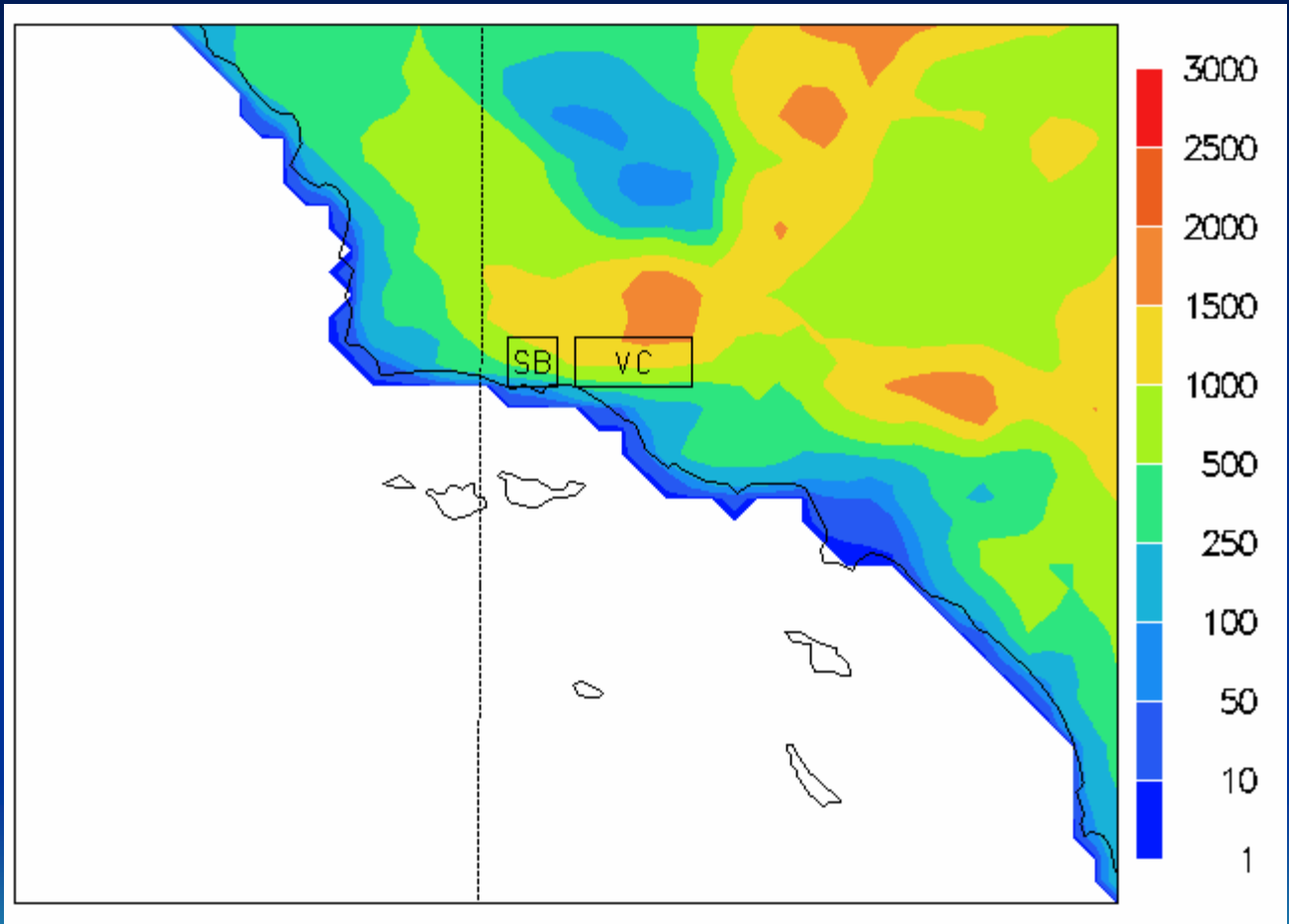
Peak Flowrates and Current Status of Streamgages		Current Q (cfs)	Q10 FEMA	ALERT Q(cfs)	FORECAST PEAK(cfs)	DATE/TIME FORECAST PK
10North Fork Matilija	(611)	700	3900.	3900.	1700	01/09 0300
9Matilija Dam (spwy 1095')	(609)	1540	2000.	6500.	6000	01/09 0345
11San Antonio Crk @ Hwy33	(663)	600	7000.	7000.	5500	01/09 0330
18Ventura @ Foster Park	(624)	2200	30000.	30000.	14000	01/09 0415
1Sespe Creek	(619)	11000	33000.	35000.	18000	01/09 0800
Pole Creek @ Fillmore	(656)	5	2000.	3000.	800	01/09 0115
Hopper Creek @ Piru	(689)	10	4000.	15000.	1800	01/09 0145
2Santa Paula @ Steckl	(646)	1640	6800.	10000.	6000	01/09 0330
19Santa Clara @ Freeman	(639)	3500	66900.	67000.	30000	01/09 1545
Arroyo Tapo @ Walnut	(2617)	10	1850.	3200.	1200	01/09 1300
7Arroyo Simi @ Madera Rd.	(627)	250	4400.	2300.	5400	01/09 1315
8Conejo Ck. abv. Hwy 101	(629)	450	4400.	6000.	4800	01/09 1330
3Calleguas Ck. @ CSUCI	(622)	800	8700.	19000.	15000	01/09 1430
4Revolon Slough	(617)	280	2200.	9000.	6000	01/09 0415

ake Casitas Dam: No spill expected;Santa Felicia Dam: No spill expected
=ESTIMATED, A=ACTUAL *snow
FLOODWATCH ongoing for Wolf Fire (Sespe); Verdale and Piru Fires (Piru to Fillmore);
Simi Fire (Simi Valley to Saticoy)

February 2, 1998 So. Cal storm case study:
The impact of GPS-PWV on the QPF in Southern California

- Investigate:
  - the impact and limitations of the GPS-PWV on the QPF in the So. Cal region.
- Two sets of simulations have been performed for a So. Cal forecast domain.
  - The control runs are initialized with the Eta-only PWV fields
  - The GPS runs are initialized with the Eta+GPS-PWV fields.
  - Both set of runs are driven by the identical large-scale forcing from the Eta analysis data.
- Investigate the QPF differences between the control and GPS runs.
- Investigate the predictability span over which the QPF is influenced by the additional GPS-PWV data.
  - Air-flow analysis related to the predictability span.

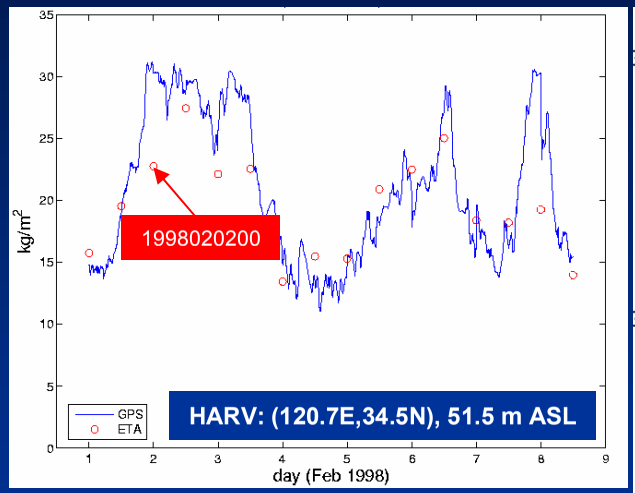
The domain and the model terrain (m) for the So. Cal case study area

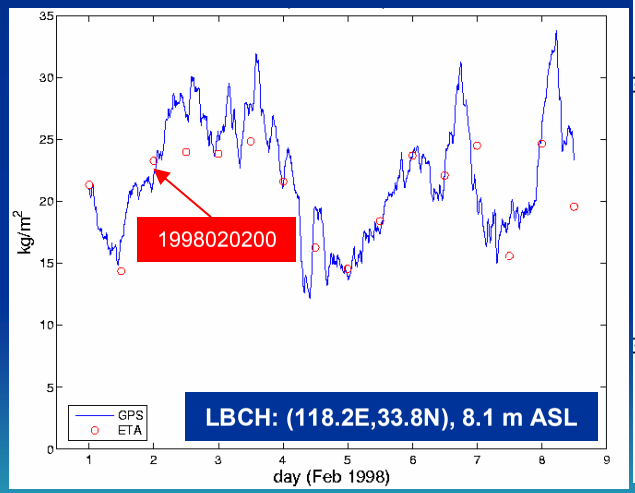


SB: Western Santa Barbara County, VC: Northern Ventura County

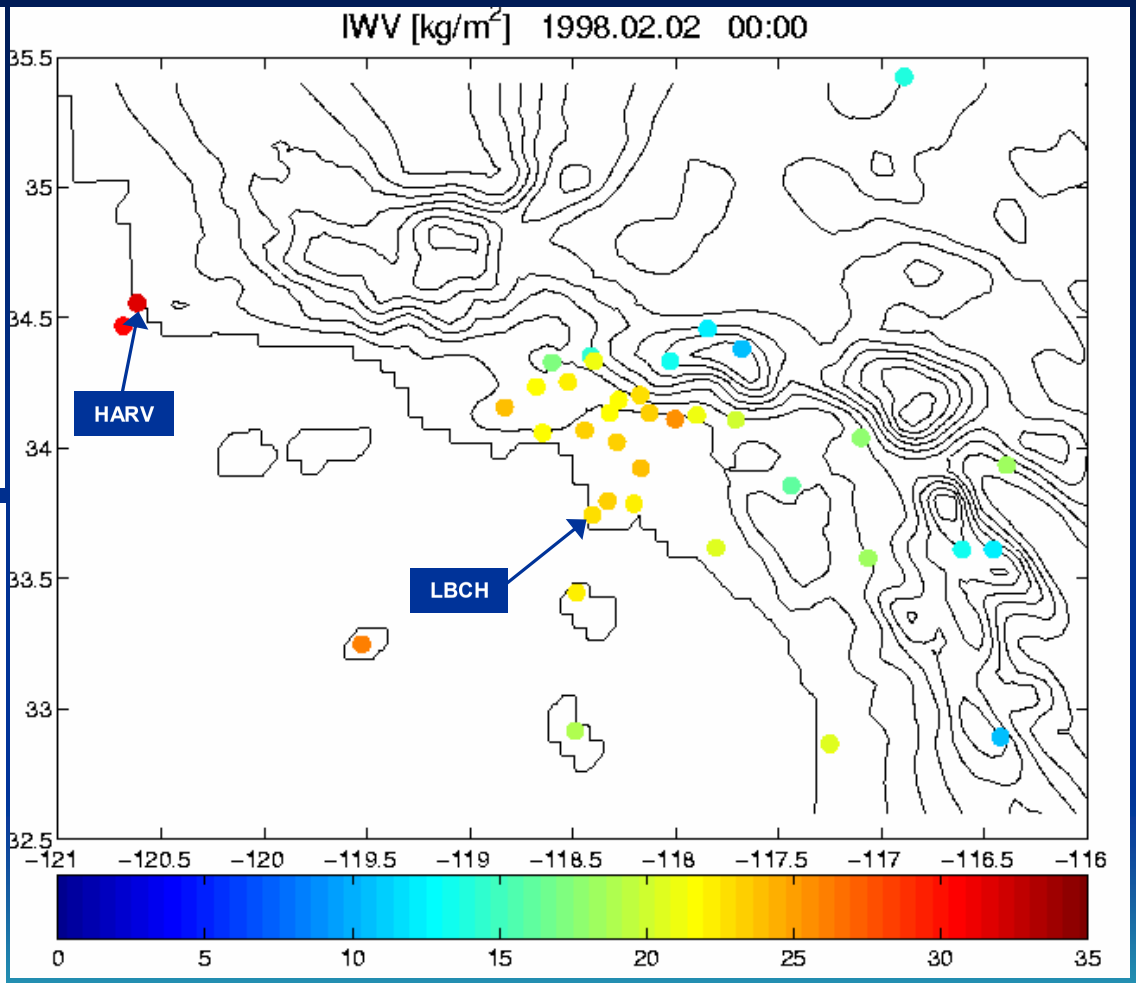
The PWV data retrieved at the SCIGN GPS sites

The PWV time series from GPS and Eta initial fields for 1- 8 Feb. 1998.



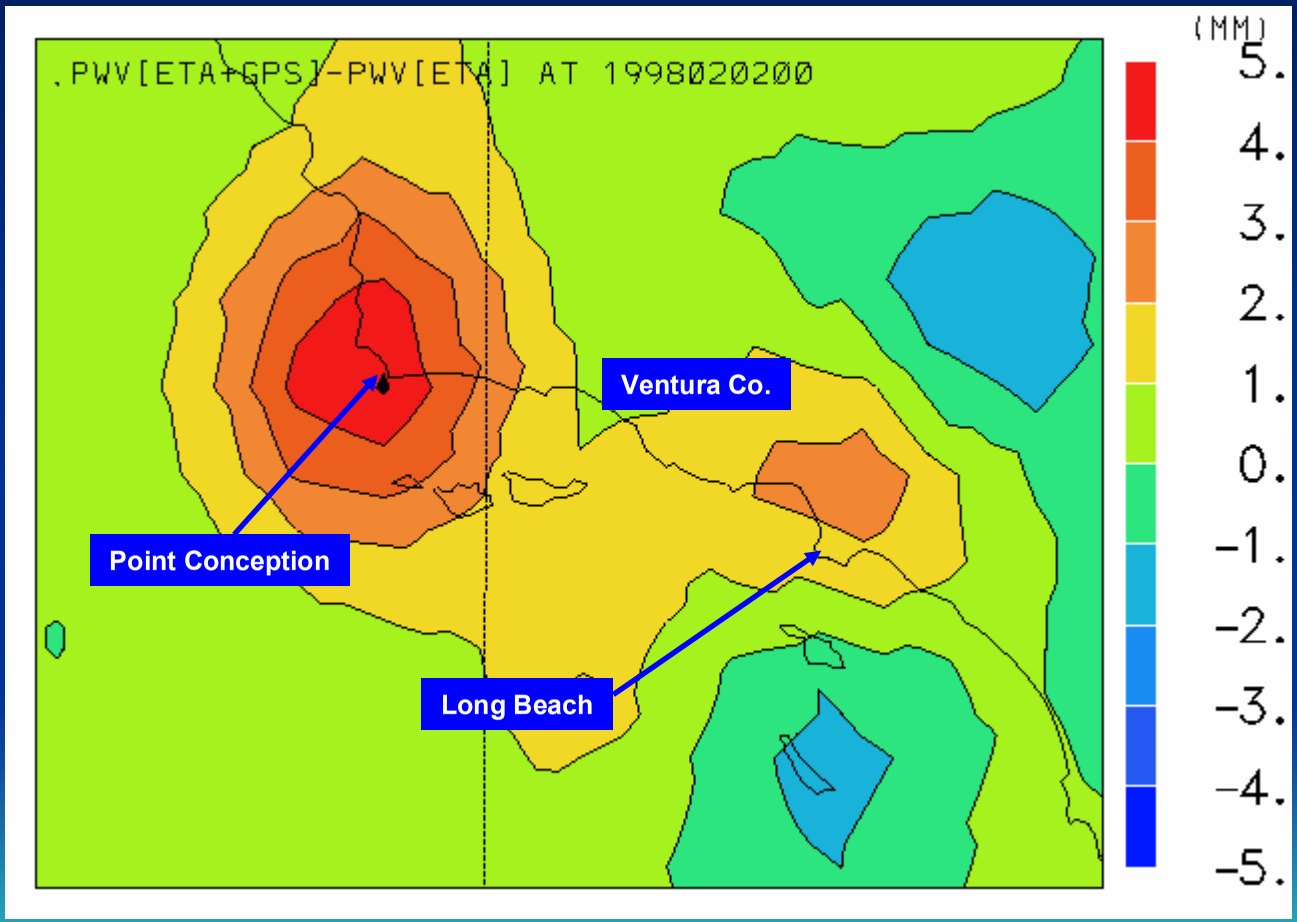


The snapshot of the retrieved PWV values (decimeters) at the SCIGN sites at 06UTC February 2, 1998.

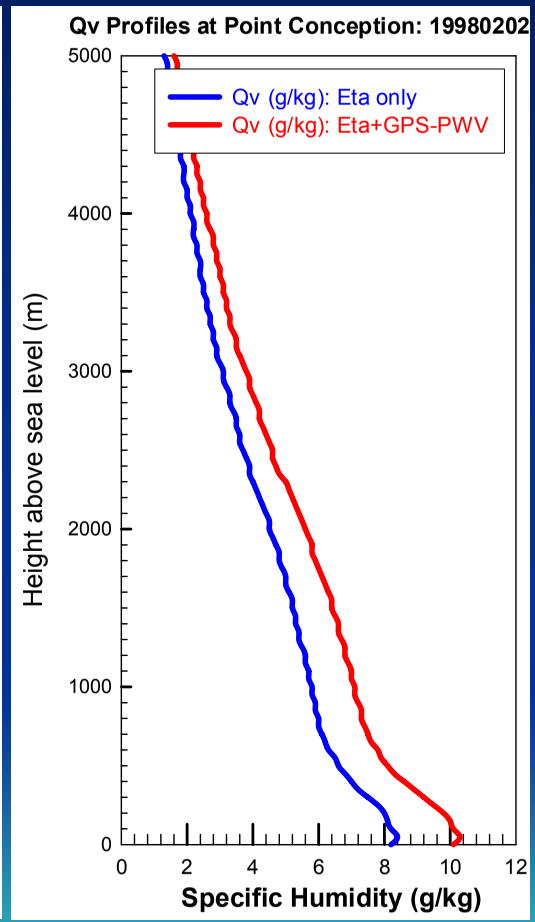


These 'local' PWV values at the GPS sites are merged with the PWV values in the operational Eta using the Cressman analysis to generate Eta+GPS PWV fields for the NWP initialization.

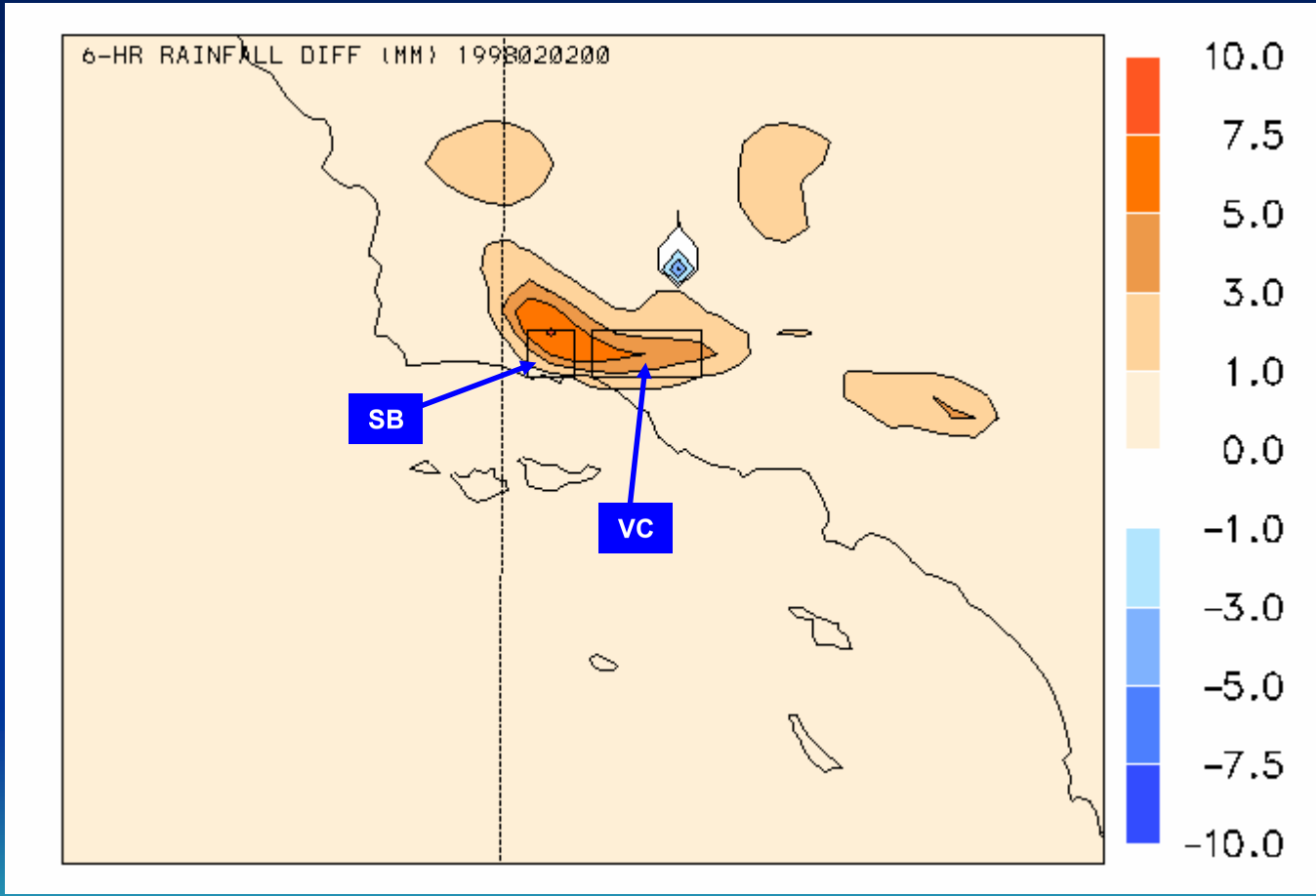
The PWV differences (mm) between the Eta-only and the Eta+GPS at 00UTC, February 2, 1998.



The Eta-only (blue) and Eta+GPS (red) specific humidity profiles at the Point Conception.

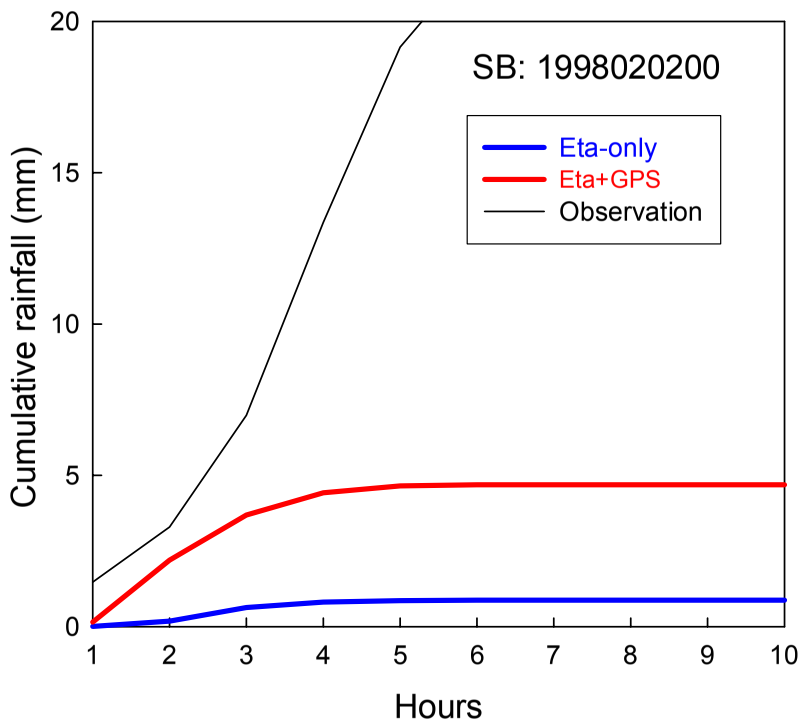


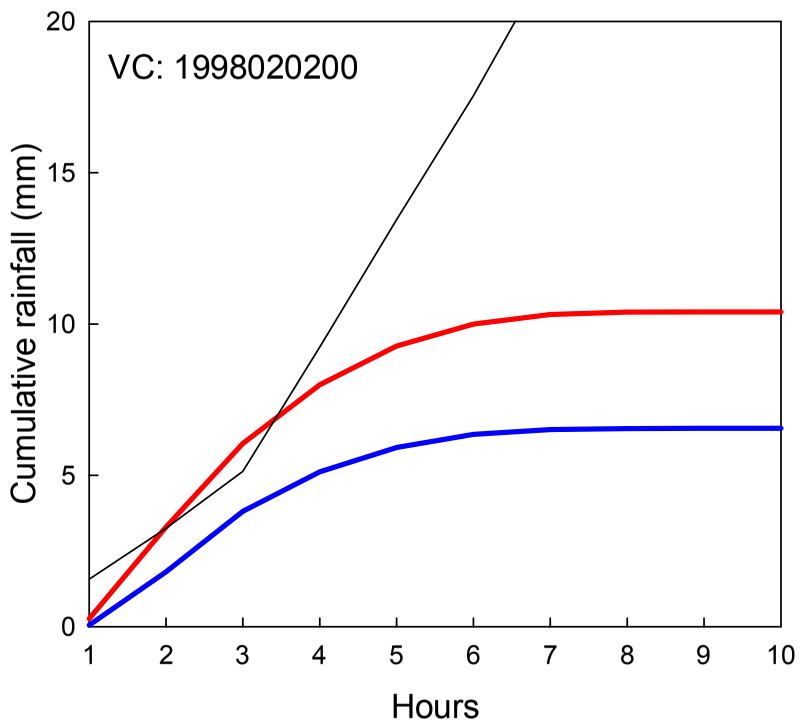
The differences between the 6-HR (00-06UTC) QPFs generated from the Eta-only and Eta+GPS PWV initial conditions



The cumulative QPF in the SB and VC regions

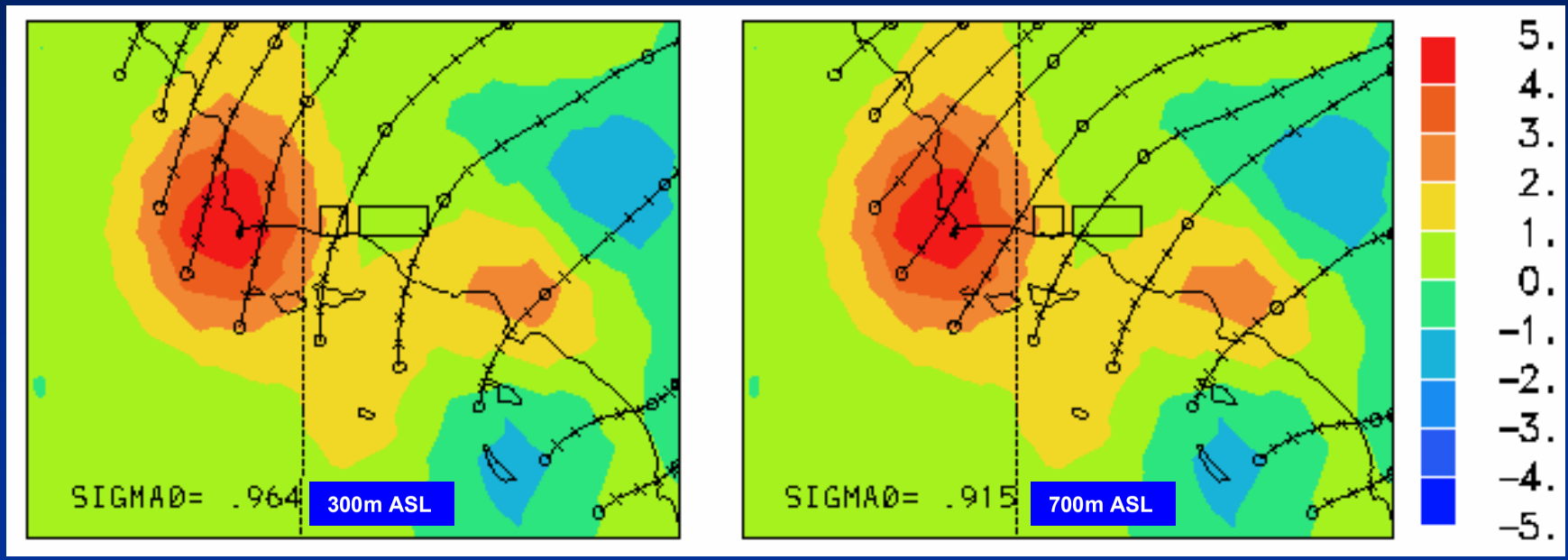
1998020200 initialization





The initial PWV differences and low-level particle trajectories: Implications on the predictability span

1998020200 Initialization



The predictability span affected by the GPS-PWV is limited by the spatial coverage of the GPS receivers in the region. The low-level particle trajectory shows that the initial water vapor fields affected by the additional PWV data from the SCIGN pass through the main forecast areas, Ventura and Los Angeles County, in 3-6 hours from the starting time. Additional water vapor data over the eastern Pacific region will be crucial for increasing the useful forecast lead time.

The area covered by AIRS water vapor measurements
A complementary source of PWV data over eastern Pacific

Relation of Fields of View of AIRS/AMSU/HSB

A granule of data contains 45 scansets, corresponding to 45 cross-track scans of the AMSU-A mirror. The AMSU-A radiance data sampled in a scanset are combined to create integrated radiances for 30 contiguous AMSU-A FOVs. An integration encompasses the time required for the mirror to sweep through an AMSU-A instantaneous FOV. Figure 2 illustrates the retrieval FOV pattern over Southern California that make up Granule 209 of AIRS/AMSU/HSB products on September 6, 2002.

Figure 2: AIRS/AMSU/HSB Footprint Pattern Sept 6, 2002; Granule 209

Summary: February 2, 1998 storm case study

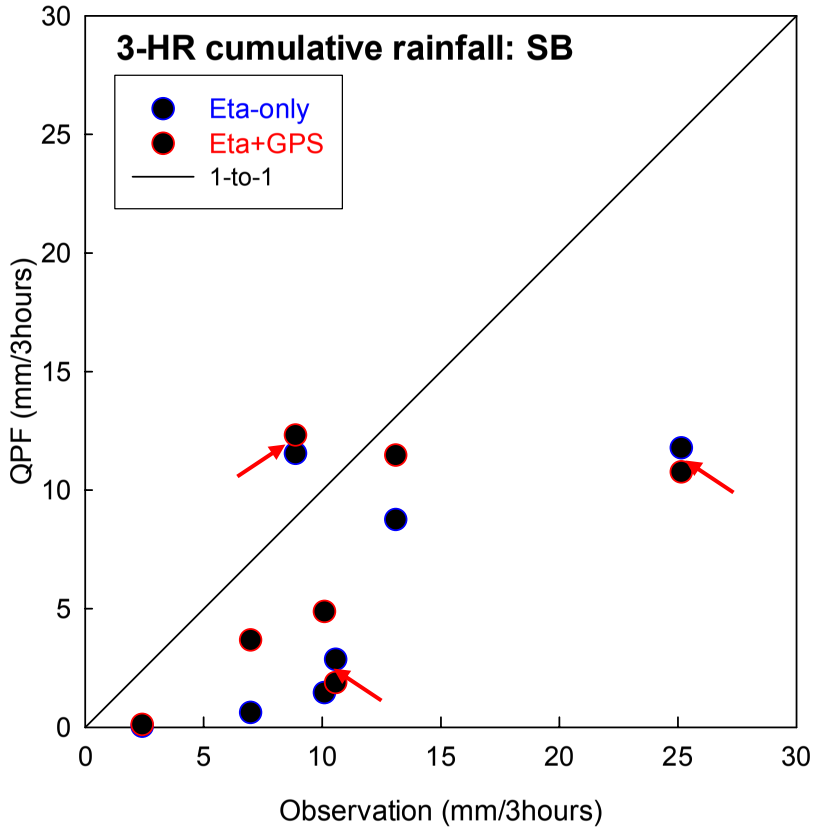
- The case study for the Feb. 2, 1998 storm event suggests that:
  - The additional PWV data from SCIGN improve the QPF in the Santa Barbara and northern Ventura County regions for the first 6-hr period.
  - A trajectory analysis suggest that the predictability span affected by the PWV data from the SCIGN array is limited by its spatial coverage, especially the lack of GPS receivers (PWV data) in the eastern Pacific.
  - Additional PWV observations over the eastern Pacific (e.g., AIRS data) will be useful for extending useful forecast lead time.

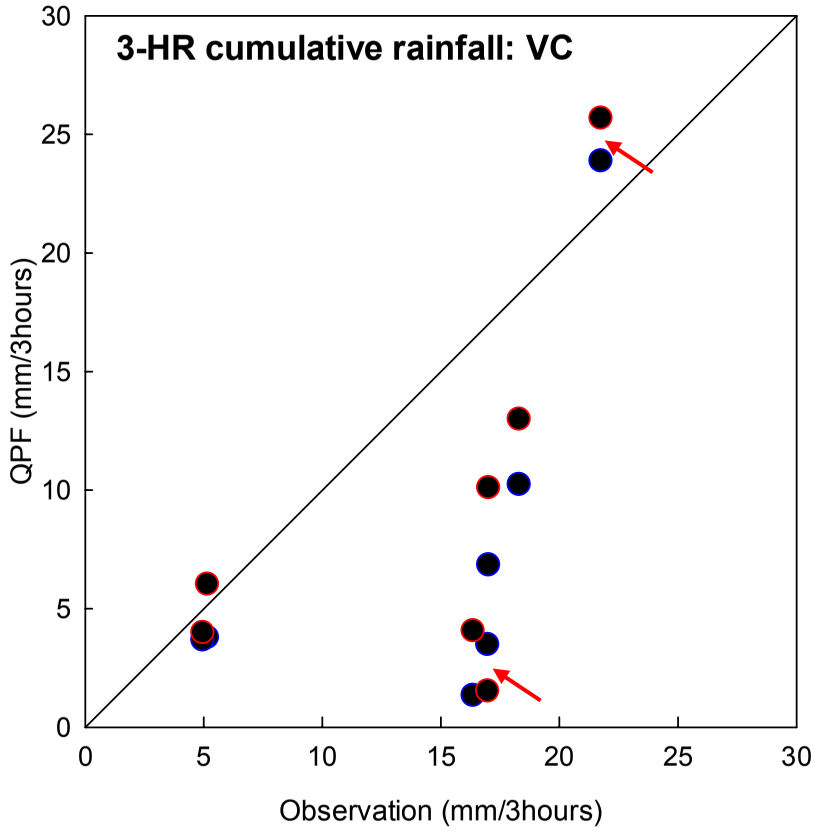
The impact of the GPS-PWV on the So. Cal QPF: 3- and 6-HR QPFs

Multiple winter storm case studies

- Examine the statistical significance of the impact of GPS-PWV on the QPFs in southern California.

3-HR QPF within the two selected regions (SB and VC)



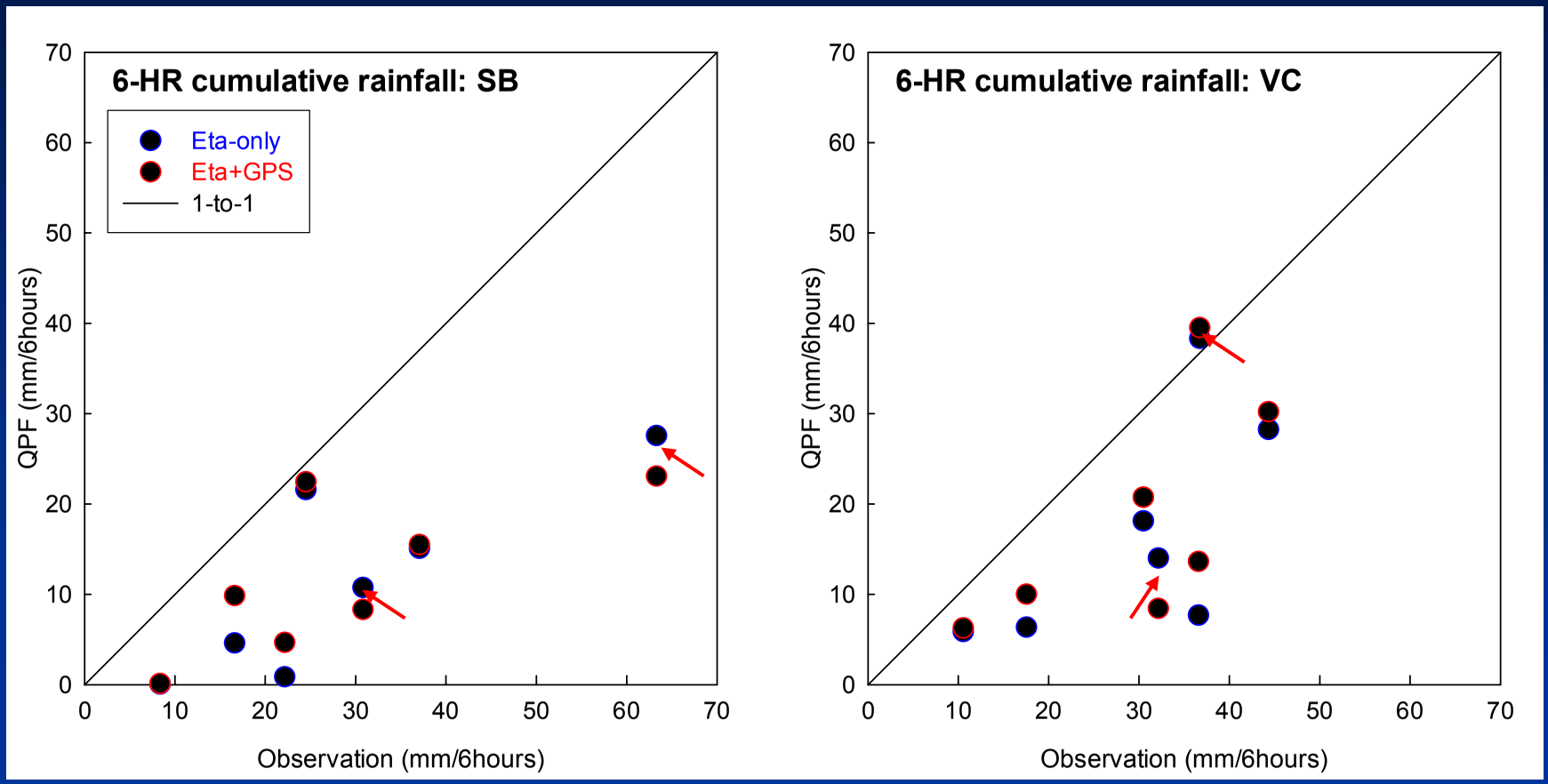


	Eta	Eta+GPS	Eta	Eta+GPS
RMSE:	7.41	6.96	9.10	8.28
AbsE:	6.49	5.56	7.32	6.52
Bias:	-5.72	-4.57	-6.71	-5.11

(1) QPF underestimates the 3-hr rainfall accumulation, in general.

(2) 3-hr QPFs are improved in 4(5) out of 7 cases in the SB(VC) region.

6-HR QPF within the two selected regions (SB and VC)



	Eta	Eta+GPS	Eta	Eta+GPS
RMSE:	20.11	20.72	15.68	14.45
AbsE:	17.46	16.95	13.26	12.15
Bias:	-17.46	-16.95	-13.26	-11.34

(1) QPF underestimates the 6-hr rainfall accumulation, in general.

(2) 6-hr QPFs have been improved in 5 out of 7 cases in both regions.

Summary: Multiple winter storm case studies

- Use of additional PWV data from the SCIGN in conjunction with the operational Eta initial analysis could improve the 3-hr and 6-hr QPFs for the Santa Barbara and Ventura County regions in most cases.

- This part of the project is in progress now. We will perform > 20 case studies to assess a statistically-meaningful impact of the GPS-PWV data on the QPF in the Southern California region.

Seasonal climate studies

- **Goal: Investigate**
  - the role of atmospheric lower boundary forcing in shaping the water cycle in the western United States.
  - the predictability span associated with surface memory.

- **Two seasonal climate studies have been performed:**
  - The impact of the Gulf of California SSTs on warm season rainfall in the North American Monsoon Region.
  - The impact of aerosol radiative forcing on surface insolation and snowmelt in California.

Seasonal Climate Study 1

The impact of the Gulf of California SSTs on warm-season rainfall in the North American Monsoon region

Motivation

- Predicting warm-season rainfall is an important concern for water resources management in the southwestern U.S. (SWUS) and NW Mexico.

- Seasonal forecasts based on dynamic models suffer from a lack of predictability due to short memory span of atmospheric circulation. Mesoscale surface forcing associated with the land surface and coastal waters may help extending the predictability of the warm-season water cycle in the region, but its roles remain unclear.

- The Gulf of California (GoC) is thought to affect the warm season water cycle in the SWUS and the NWM:
  - The *GoC may be the main source of moisture for monsoon rainfall in AZ-NM* (Douglas et al. 1993, Stensrud et al. 1995).
  - Mitchell et al. (2002) suggest that the GoC SSTs are a precursor of the onset of monsoon rainfall in AZ-NM and NWM. They observed that *warming of the GoC is strongly correlated with northward advances of monsoon rainfall in the NWM and AZ-NM*. Despite the strong relationship, their study can not determine *if the warming of the GoC is necessary for the onset of monsoon rainfall in AZ-NM*.

Experimental design

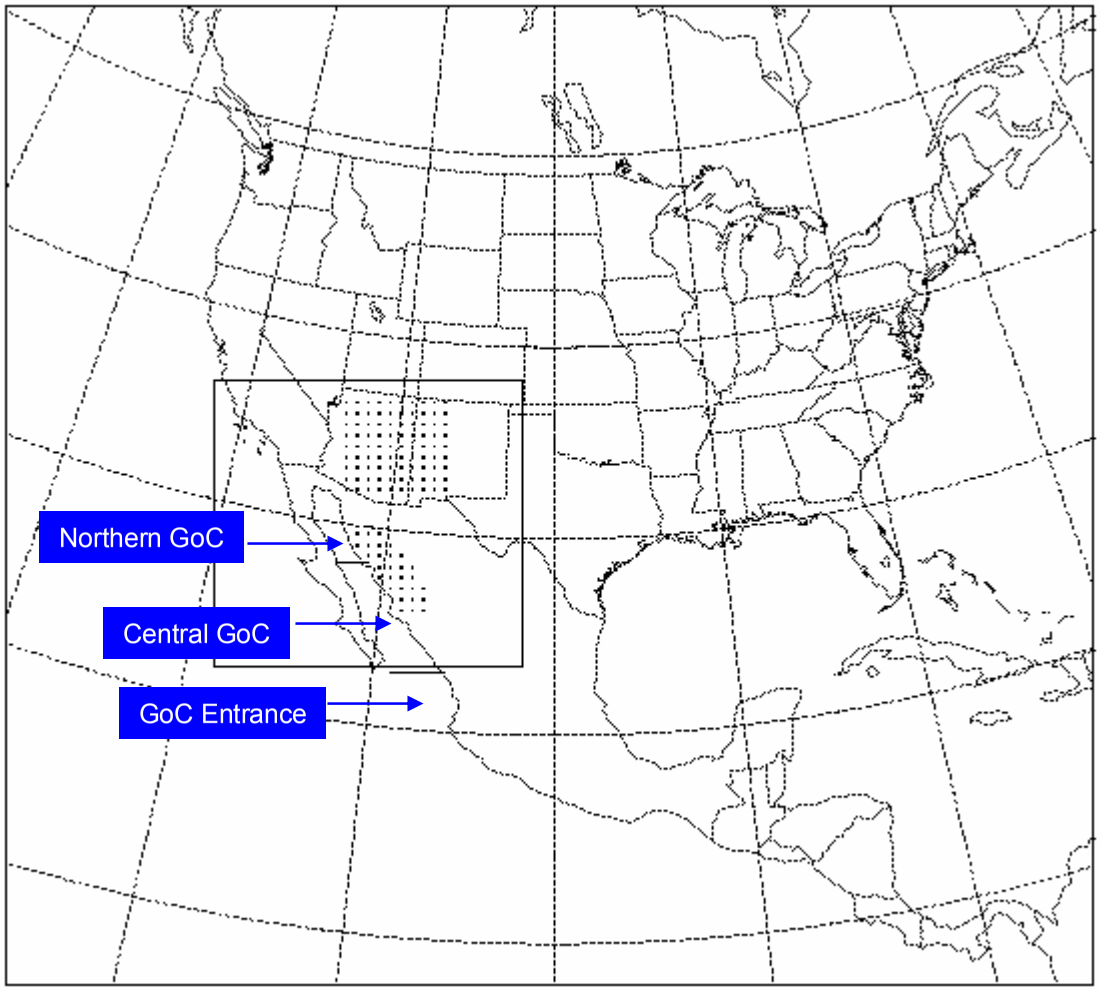
- Examine the effects of the GoC SST on the warm-season water cycle in AZ-NM and the NWM during the NAM from multiple seasonal simulations. In particular, we focus on the impact of the GoC SSTs on
  - The onset timing of monsoon rainfall in the AZ-NM region, and
  - The mesoscale circulation and rainfall around the GoC.

- **Contrast the results from the control and sensitivity runs:**
  - ***Control***: The GoC SST are prescribed from the NCEP Reanalysis 2. *The GoC SSTs in the run are lower than observations by as much as 5 K.*
  - ***Sensitivity (GOC6)***: The GoC SSTs are increased from the control run by 2 K, 3 K, and 6 K in the entrance, southern and northern parts of the GOC.

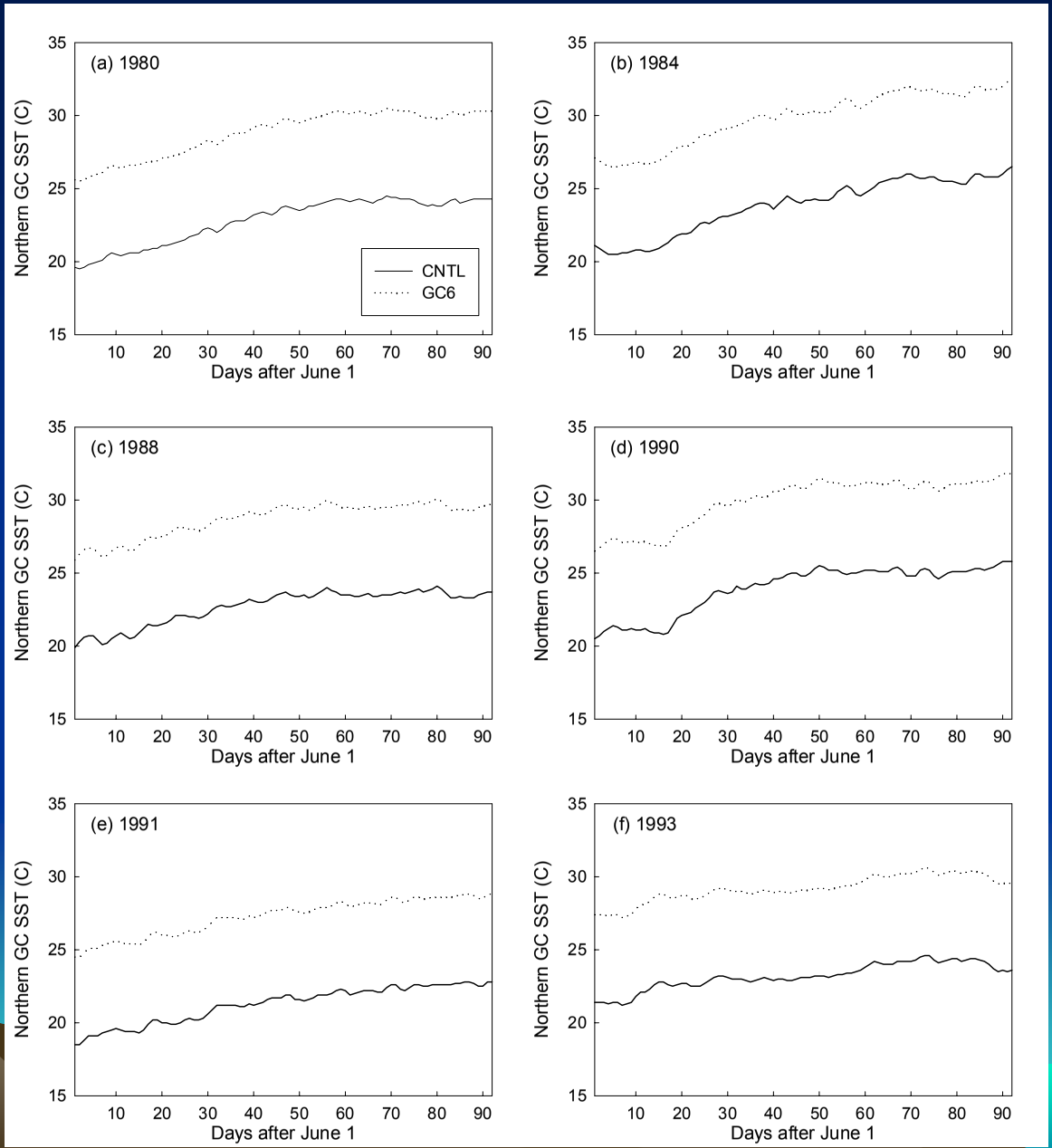
- **The model domain** covers the continental U.S. and Mexico with a horizontal resolution of 60km x 60km and 12 vertical layers (7 layers below σ=*0.7*).

- Six seasonal simulations, from June to September, have been performed for the years 1980(*D*), 1984(*W*), 1988(*W*), 1990(*W*), 1991(*N*) and 1993(*D*).

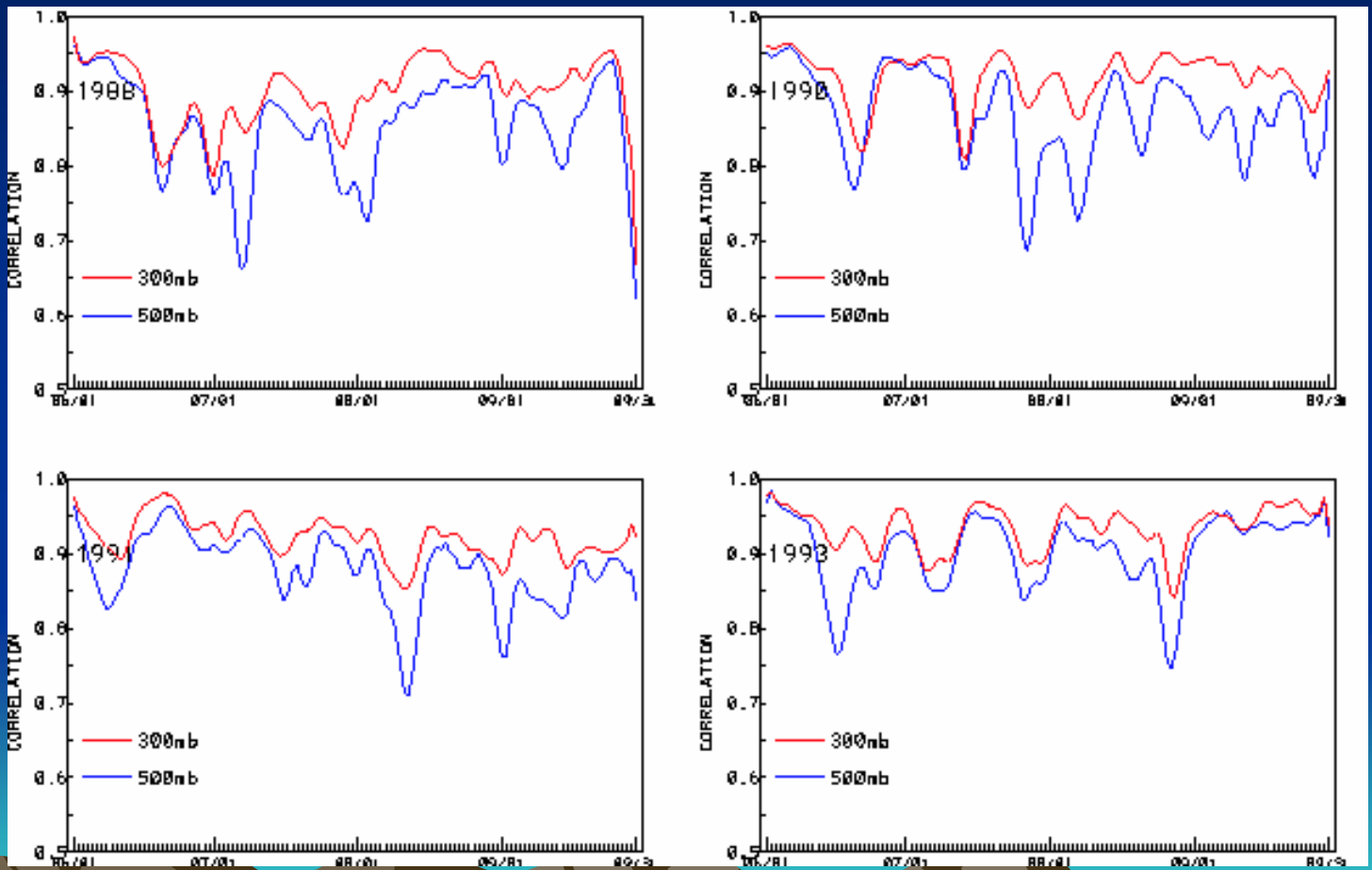
The model domain for the GoC SST study



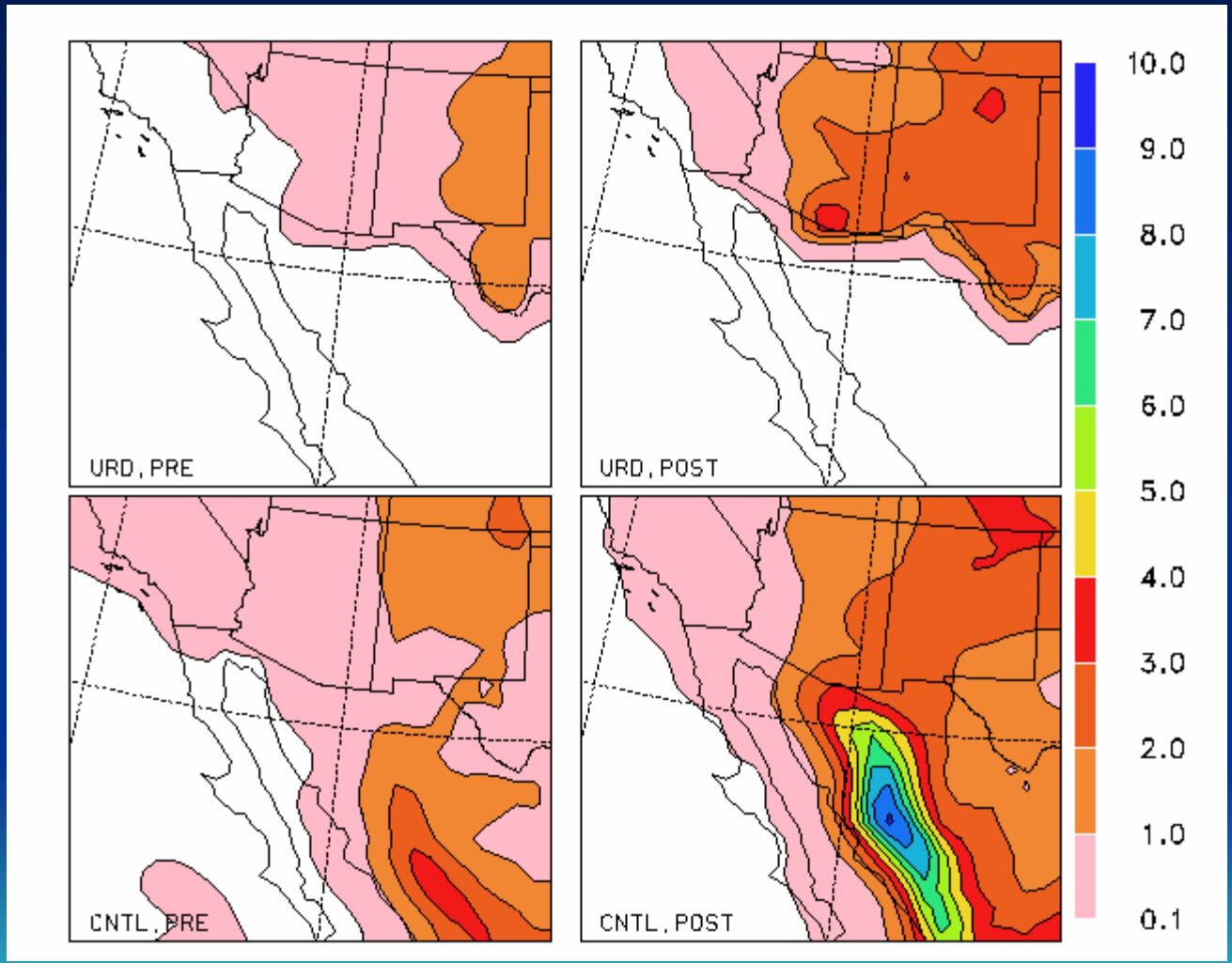
The time series of the northern GoC SSTs in the CNTL and GOC6 runs



Daily spatial anomaly correlations between the simulated and the ECMWF 300 hPa- and 500 hPa geopotential heights

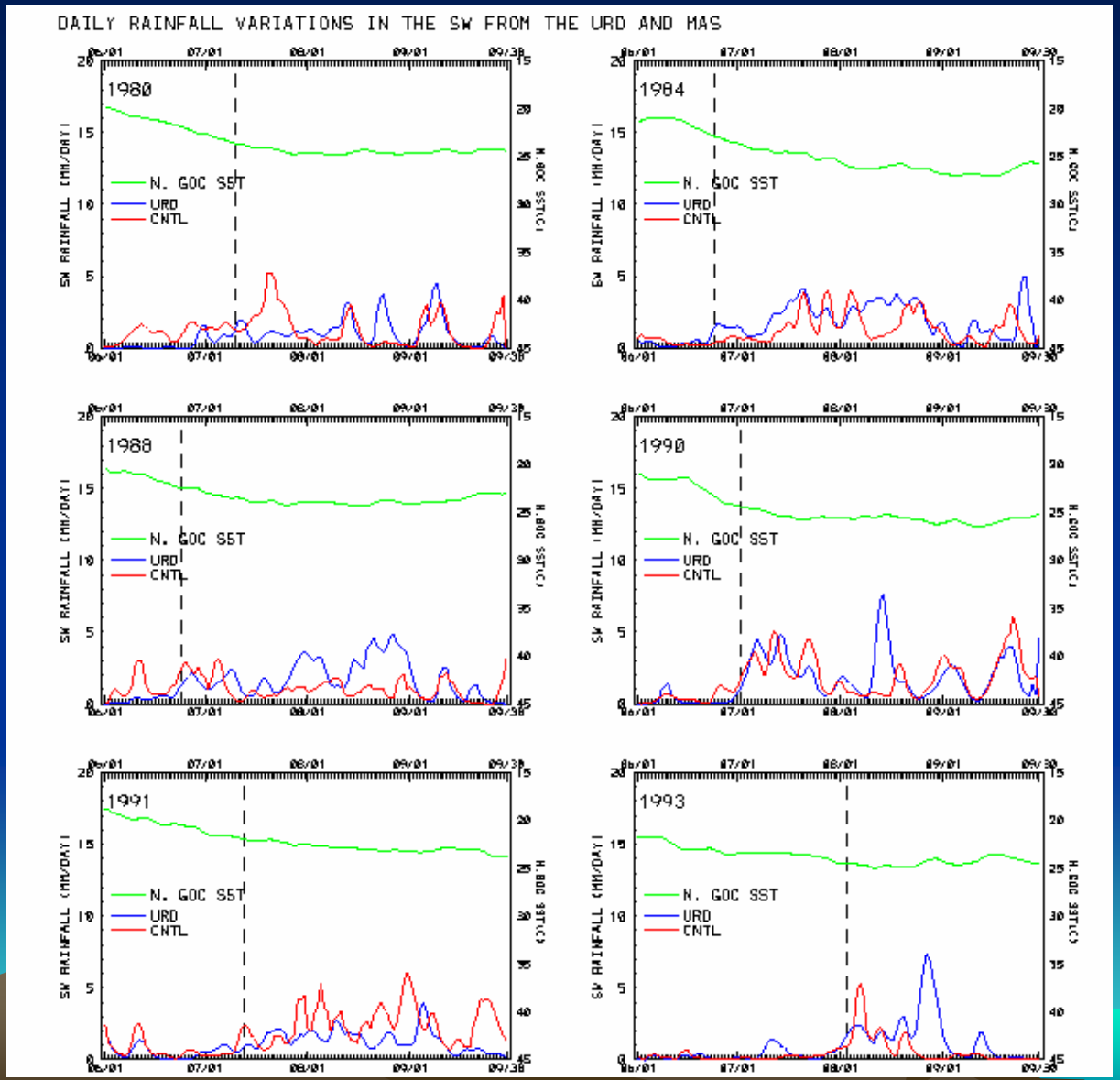


The 6-year mean rainfall for the pre- and post-onset period form the URD observation and the seasonal simulations



The daily rainfall (mm/day) in the SWUS:

CNTL (red) and NCEP-URD analysis (blue)



The control run has simulated important features of warm season rainfall in the SWUS such as:

- Temporal evolution of the upper level fields during the monsoon season
  - The GPH anomaly correlations between the simulation and the ECMWF reanalysis remain > 0.7 at the 500hPa and 300hPa levels.
- The 30-day rainfall averages for the *pre-* and *post-onset* periods [w.r.t. the observed monsoon rainfall onset dates in AZ-NM by Higgins et al. (1997)] in the *CNTL* compares well with observations.
- The sudden increases in rainfall around the time of the observed onsets are reasonably simulated in the *CNTL*.

despite the fact that the SSTs in the northern GoC are lower than observations by as much as 5 K in the *CNTL*.

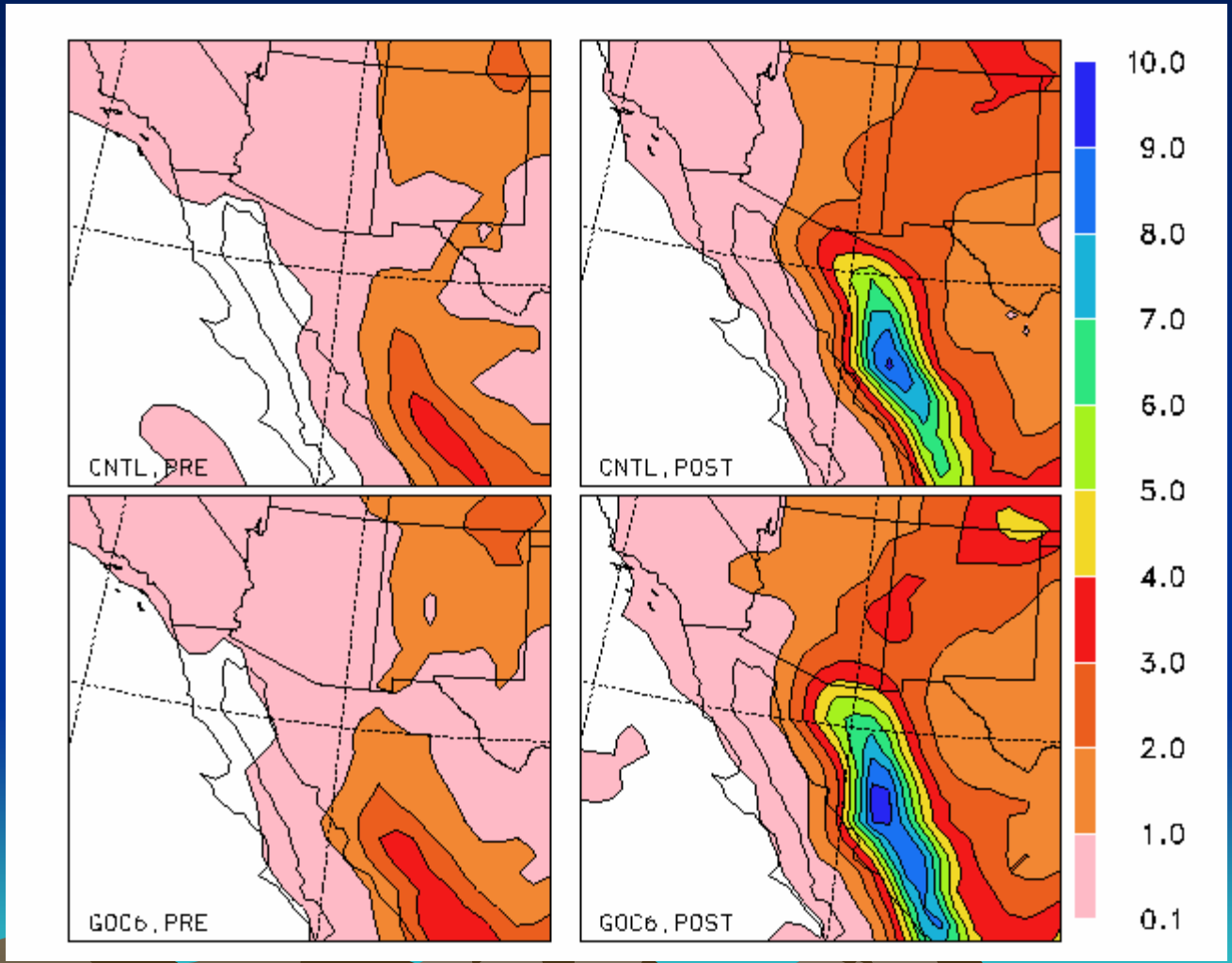
The impact of higher GoC SSTs on warm season rainfall

- Despite the fact that the SSTs in the northern GoC are lower than observations by as much as 5 K in the CNTL, the CNTL run simulates most of important features of warm season rainfall characteristics in the NAM region, at least qualitatively.

- If so, how important are the GoC SSTs in shaping the warm season water cycle in the SWUS?
  - The CNTL suggests that the warming of the northern GoC may not be the driving force of the monsoon rainfall onset.
  - BTW, the close correlations between the GoC SSTs and monsoon rainfall onsets do not prove/disprove the cause-effect relationship between the warming of the GoC and monsoon rainfall onsets.

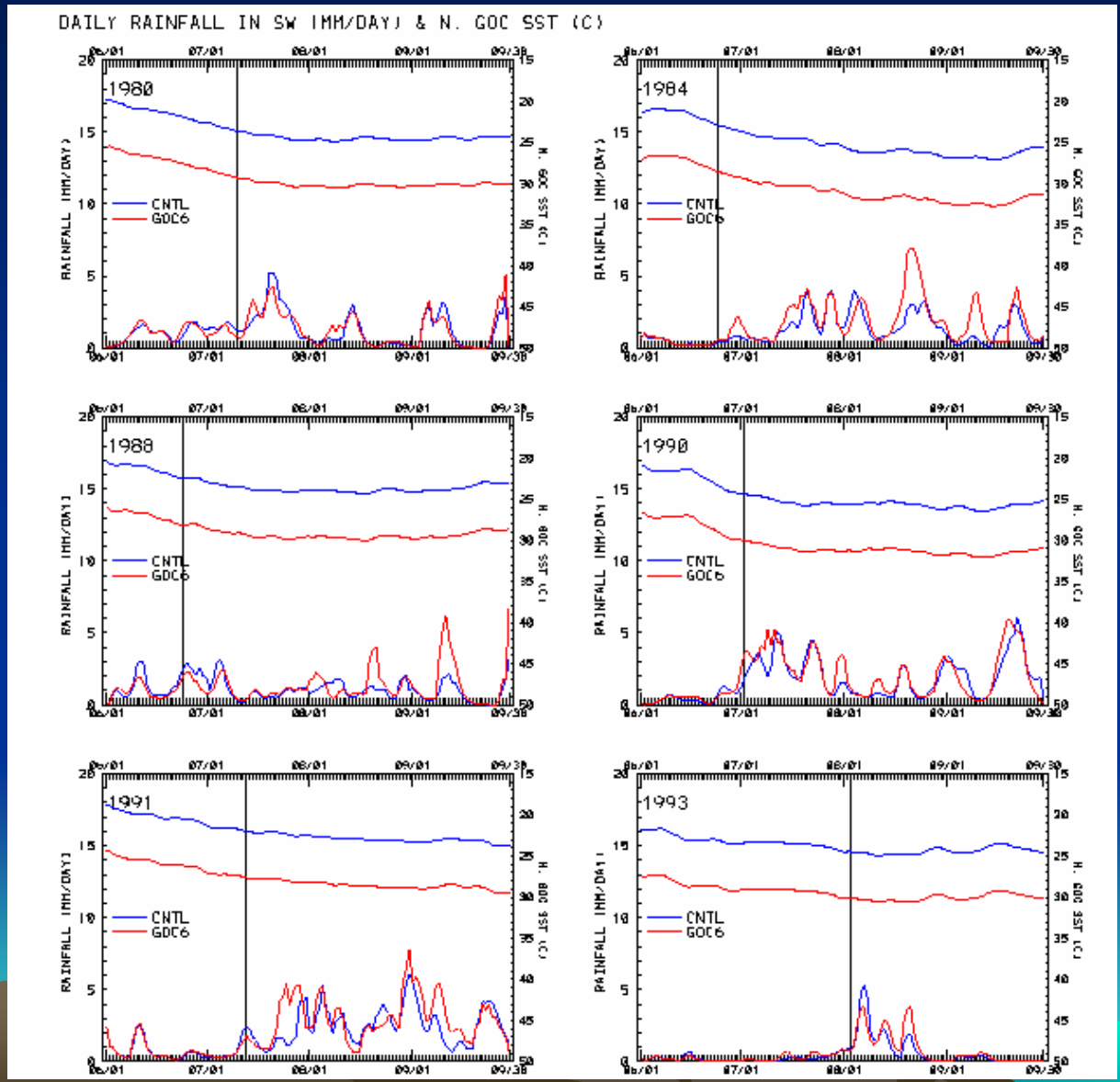
- Examine the effects of the GoC SSTs:
  - On the temporal variations in warm season rainfall
  - On the mesoscale circulation that plays an important role in shaping the warm season water cycle in the SWUS region.

The mean rainfall (mm/day) during the pre- and post-onset period in the CNTL and the GOC6 runs



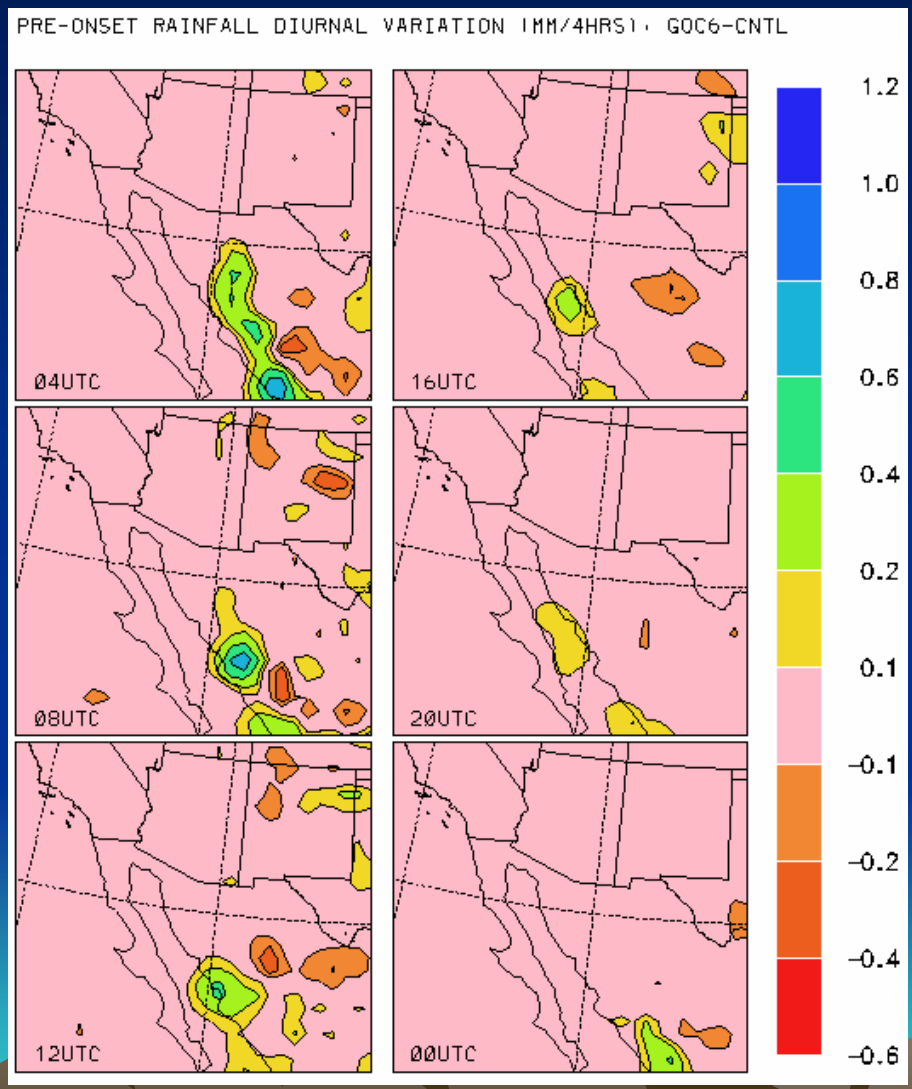
The daily rainfall (mm/day) and SSTs

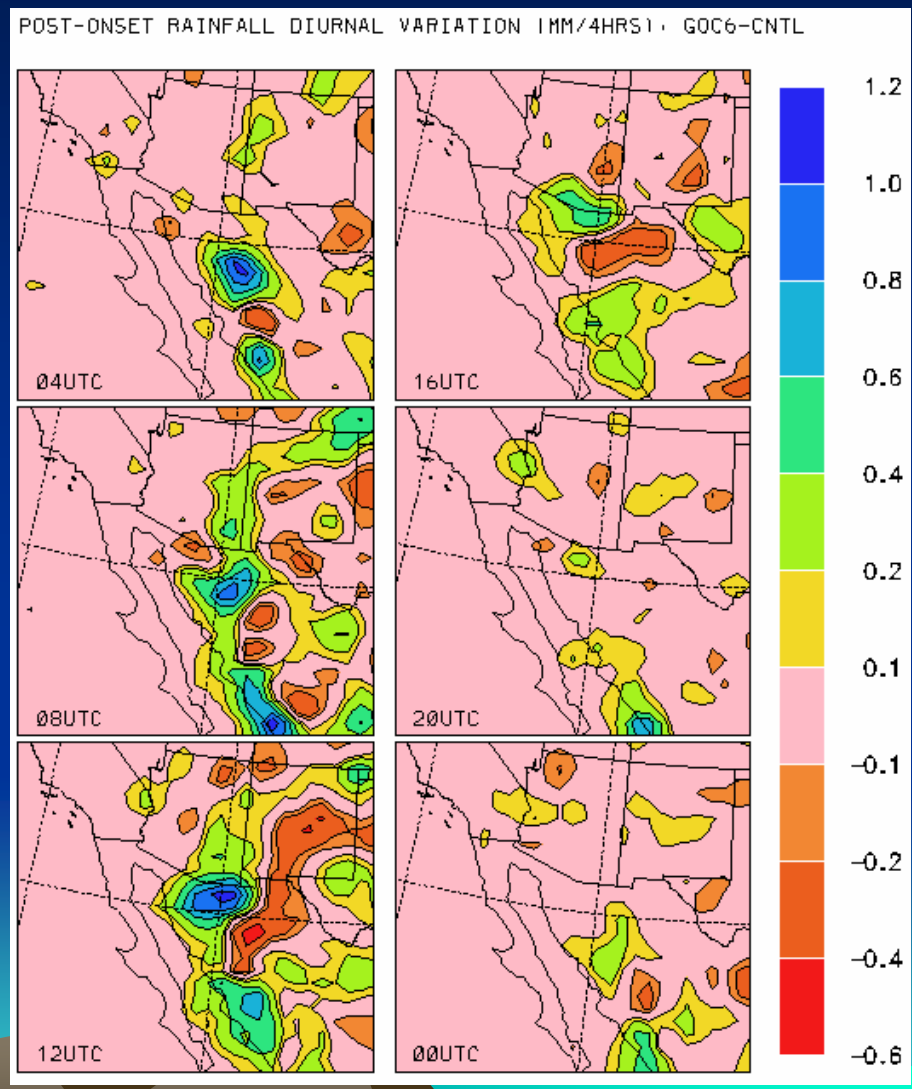
CNTL (blue) and GoC6 (red)



GOC6-CNTL: Rainfall (mm/6hrs) diurnal variations

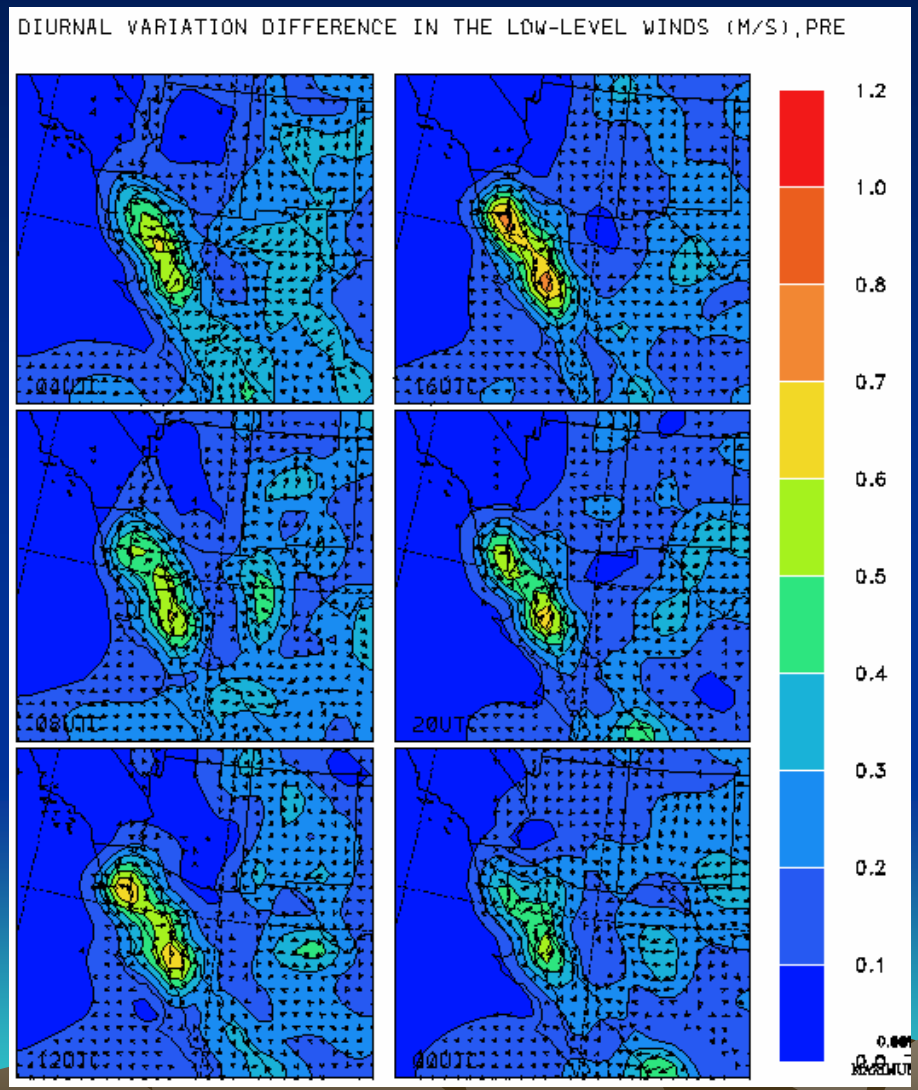
Pre- and Post-onset periods

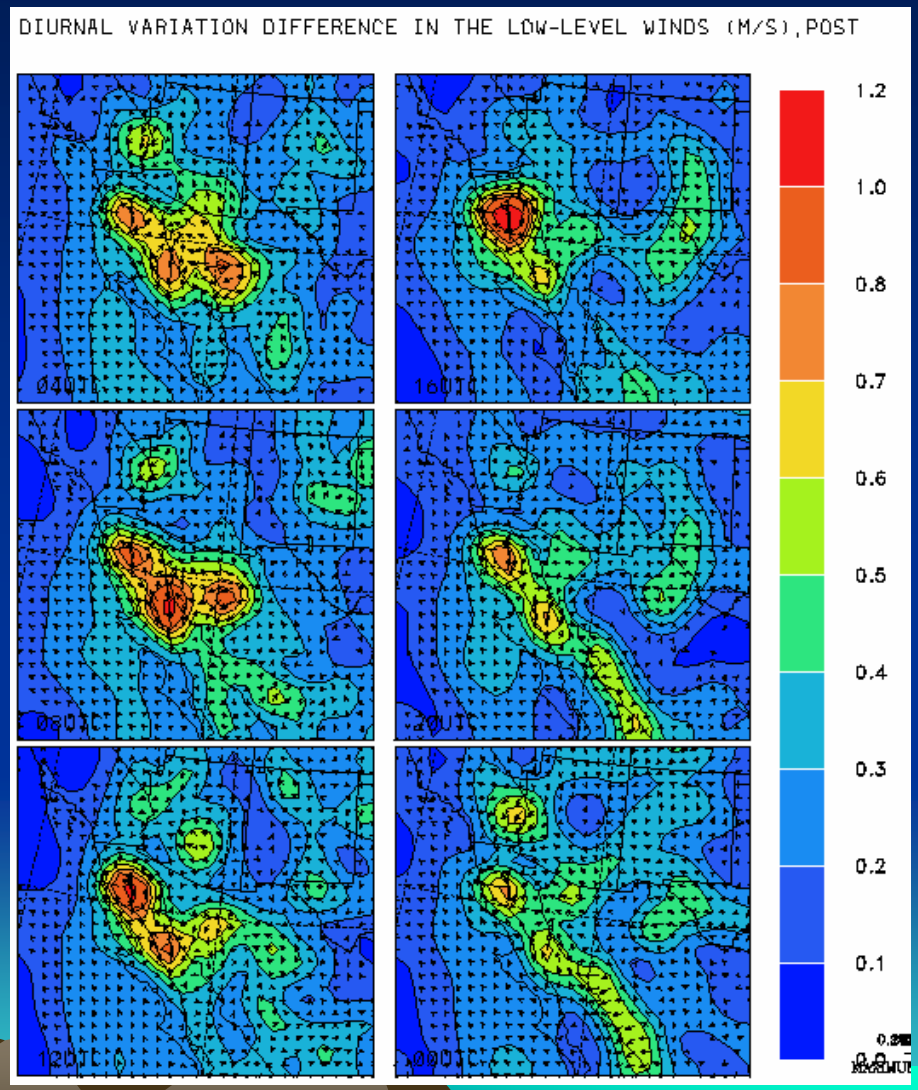




GOC6-CNTL: 10-m Winds (m/s) diurnal variations

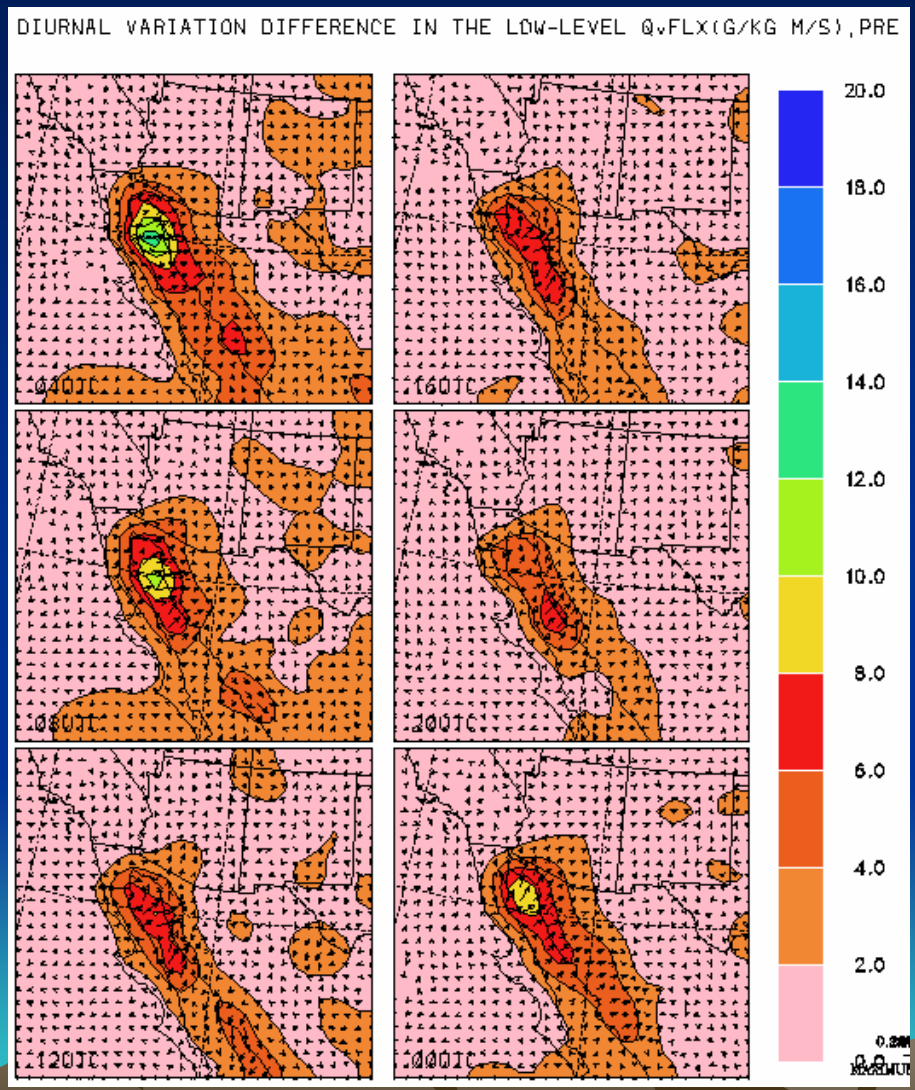
Pre- and Post-onset periods

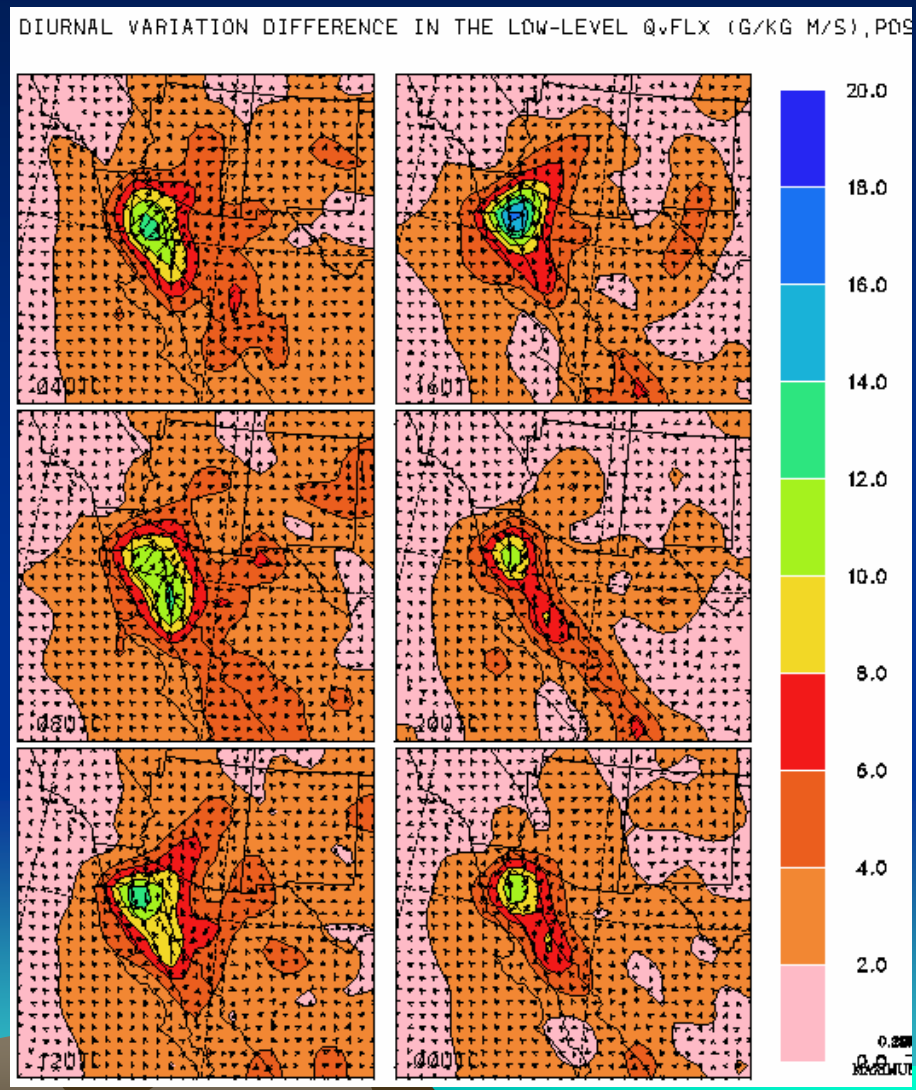




GOC6-CNTL: 10 m Water vapor flux [(g/kg)(m/s)] diurnal variations

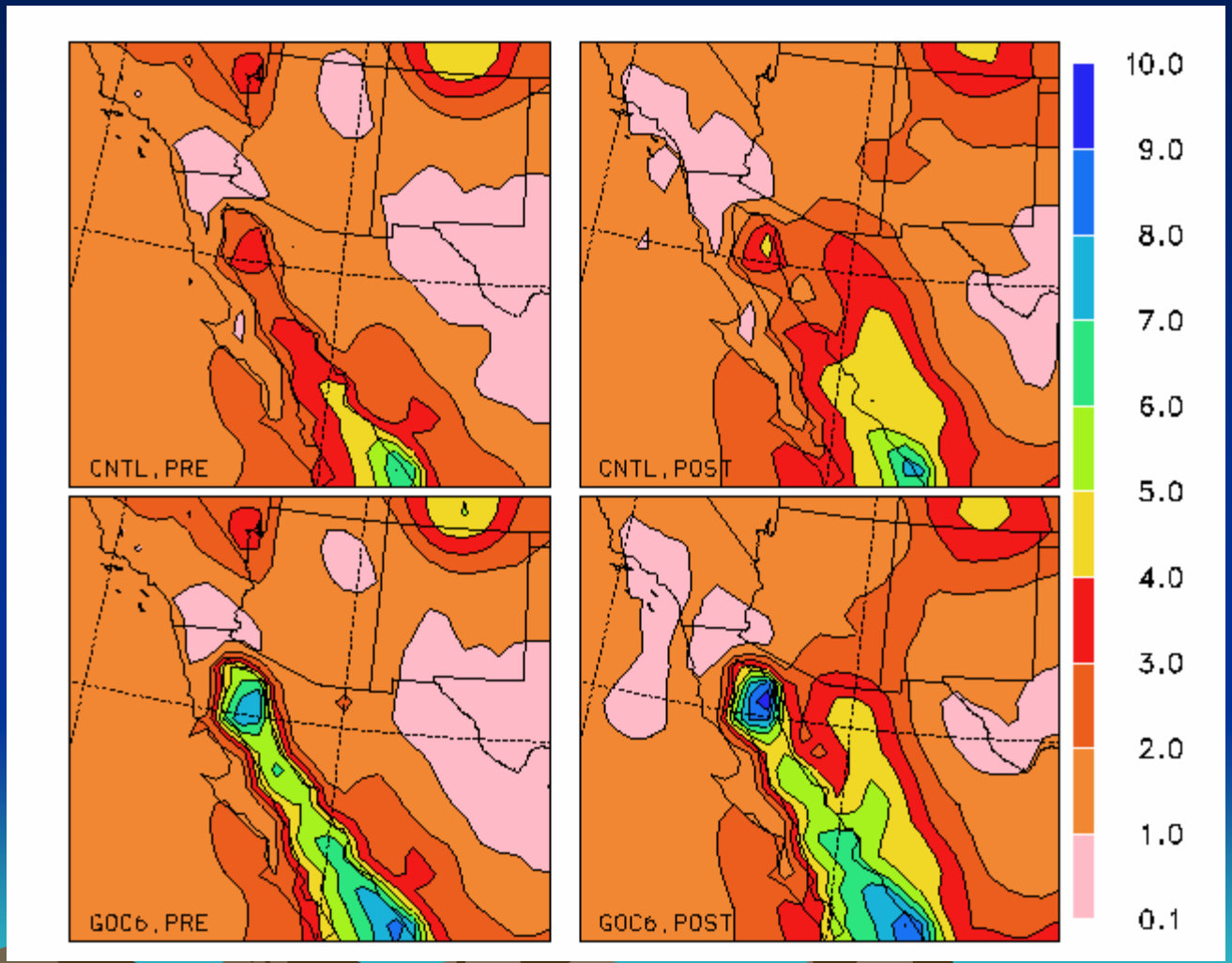
Pre- and Post-onset periods





GOC6-CNTL: Evaporation (mm/day)

30-day mean during the pre- and post-onset period



Summary: The impact of the GoC SSTs on warm-season rainfall in the North American Monsoon region

- The results suggest that *the GoC SSTs are not the primary forcing behind the northward migration of the NAM rainfall and the timing of the onset of monsoon rainfall in AZ-NM*.
- The GOC SSTs play an important role in shaping the water cycle in the AZ-NM and the NWM regions, but their impact is mostly confined to the regions in the vicinity of the GOC.
  - The GOC SSTs affect the low level moisture fluxes into the surrounding land areas (the western slope of the SMO and the SWUS) that play a crucial role in determining warm season rainfall in AZ-NM and NWM.
  - Warmer GoC SSTs tend to reduce the intensity of sea-breeze-like circulation between the GOC and the land region by reducing the land-sea temperature contrast during the daytime (negative impact).
  - Warmer GoC SSTs increase evaporation over the GOC (positive impact).
  - These two opposing effects result in the increases in water vapor fluxes from the GoC and the surrounding land, and results in higher rainfall.
  - The effects of GOC SSTs appear to be largest during the *post-onset period*.
- Accurate GOC SST data are needed for quantitative examinations of the effects of the GOC SSTs on the regional water cycle.
- The mechanism that leads to almost simultaneous evolution of the GOC SSTs and monsoon rainfall are not clear.

Seasonal Climate Study 2

The Impact of Direct Aerosol Radiative Forcing on the Surface Insolation and Snow Budget in California

Motivation

- Atmospheric aerosols play an important role in shaping water and energy cycle, but their role in the climate system remains uncertain.

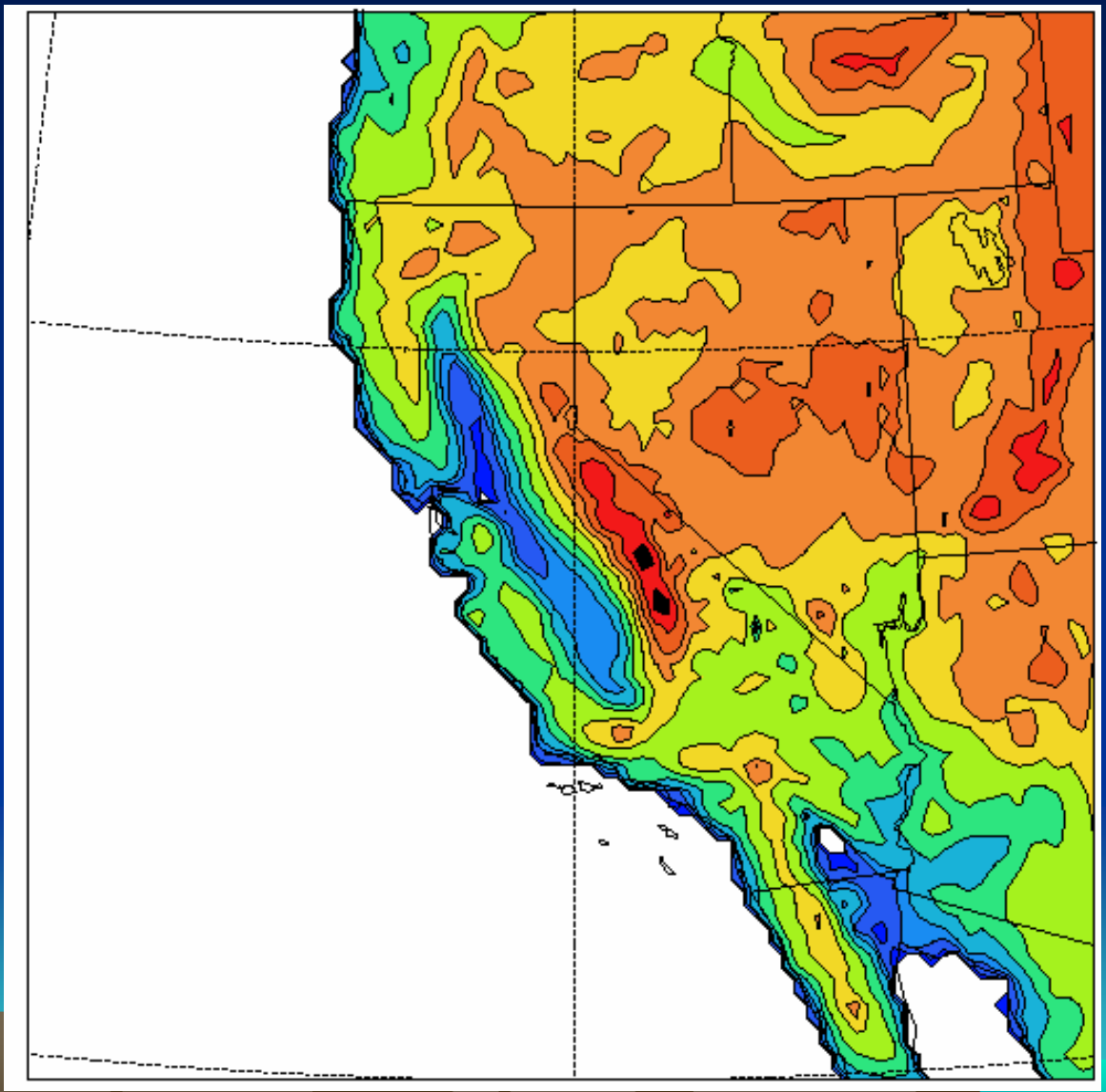
- The impact of the aerosol radiative forcing on spring snowmelt via insolation is a great interest in the WUS.
  - Warm-season snowmelt is an important source of water supply.
  - Alterations in spring snowmelt characteristics can further affect water and energy cycle through snow-albedo feedback.

- In mountainous regions, complex terrain can influence the impact of the aerosol radiative forcing on surface hydrology (e.g., Kim 2001).
  - Large elevation changes affect cloud impacts.
  - Large low-level temp changes may complicate the response of local snow budget to alterations in surface insolation.
  - Understanding the relationship between orography and physical processes that shape regional climate is an important step towards advancing climate research, especially for projecting climate impact assessment.

Experimental design

- **Goal:** Examine the impact of the direct aerosol radiative forcing on surface insolation and snowmelt in the southern Sierra Nevada region.
- **Control simulation (CNTL)**
  - Aerosol-free atmosphere. Only cloud radiative forcing is included.
- **Aerosol simulation (AERO)**
  - Time-invariant column-integrated aerosol optical depth of 0.2 is prescribed. The aerosol optical depth is subsequently re-distributed in the vertical assuming an aerosol scale height of 3 km.
  - The indirect aerosol radiative forcing effect is not included.
  - Cloud radiative forcing is included.
- **Simulation period:** The spring of March-April-May, 1998.
- **The model domain**: covers California and Nevada at an 18 km resolution and 20 atmospheric layer and 4 soil layers.
- **The large-scale forcing is from the NCEP/DOE R-2.**
- **The model output data are analyzed for 6 elevation bands (0-1 km, then at 500 m intervals up to 3.5 km).**

The Domain and the Model Terrain (18 km X 18 km)

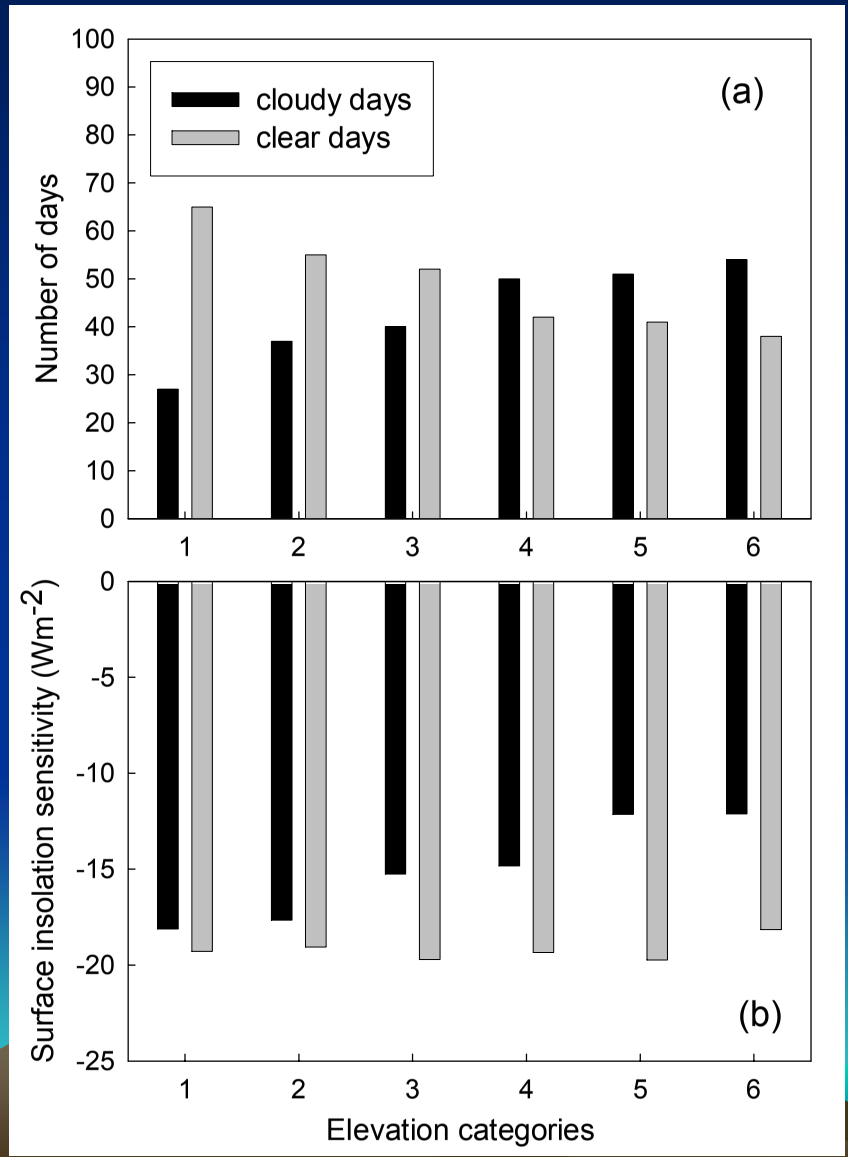


Why do the impacts of aerosol radiative forcing on surface insolation and snowmelt depend on terrain elevation?

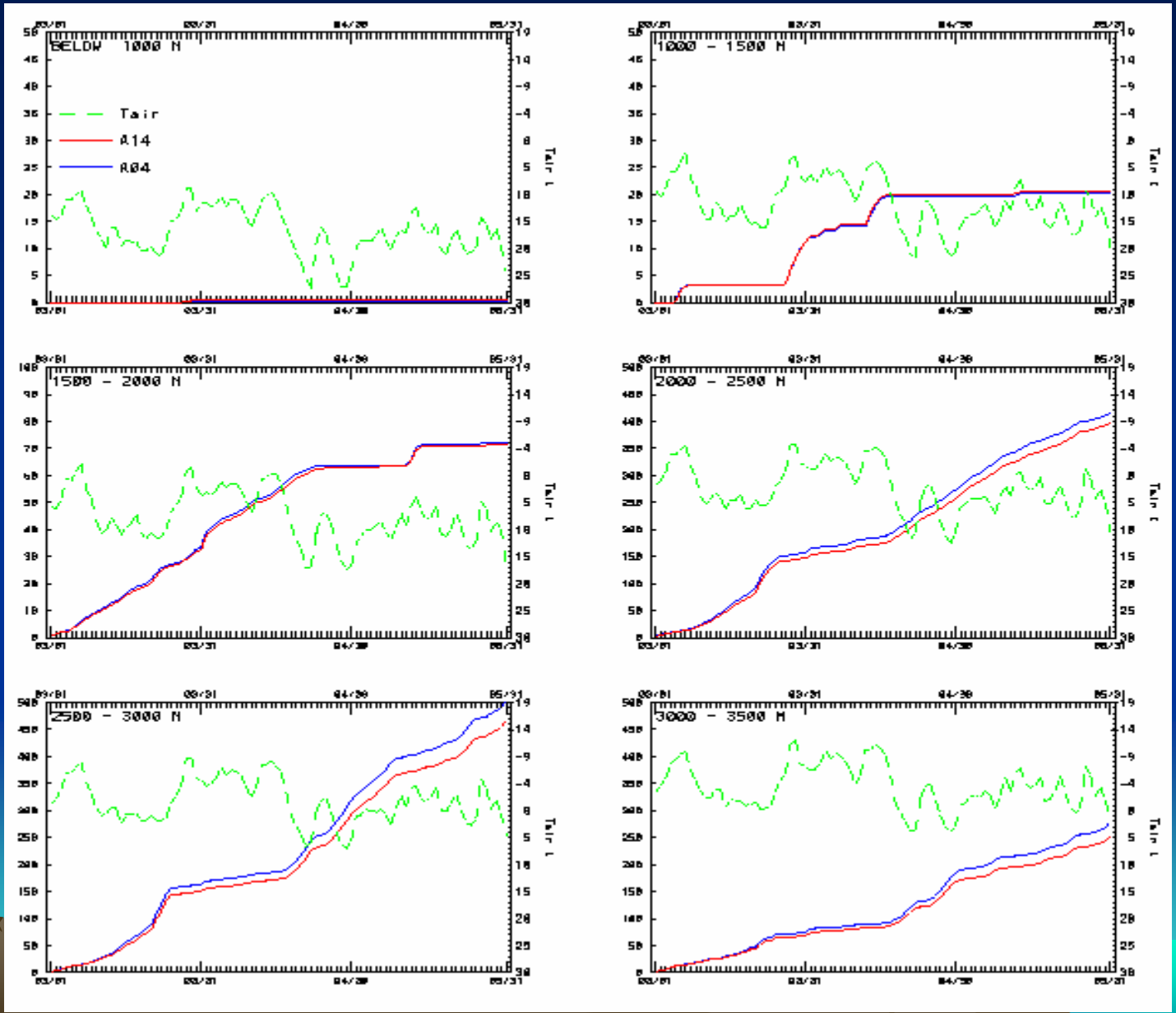
- ***The aerosol radiative forcing on surface insolation during cloudy and clear days***

- ***Snowmelt***
  - **vs. insolation changes**
  - **vs. low-level air temperatures**

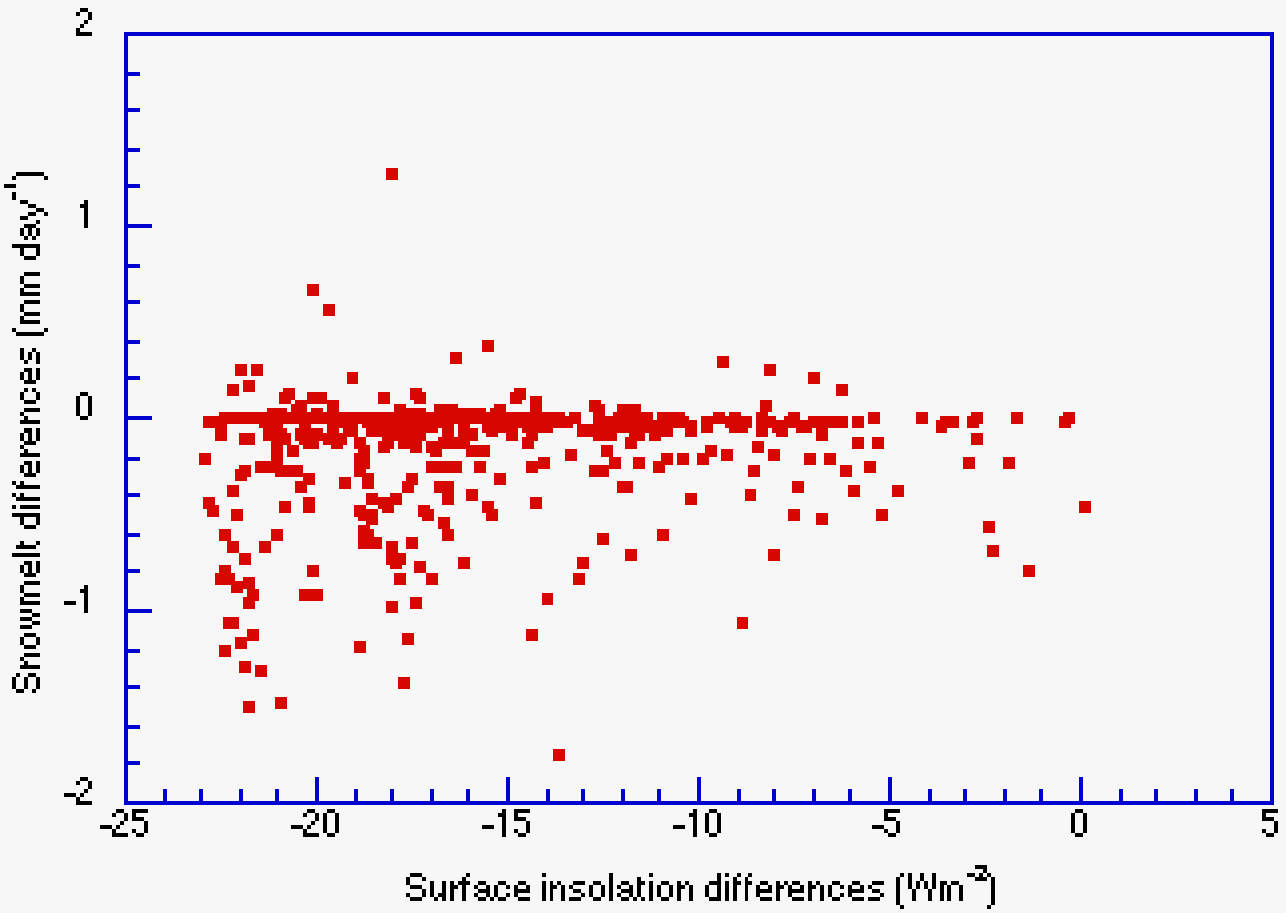
Seasonal mean δ*Insolation* due to the Direct Aerosol Radiative Forcing during Clear and Cloudy Days within Different Elevations Bands



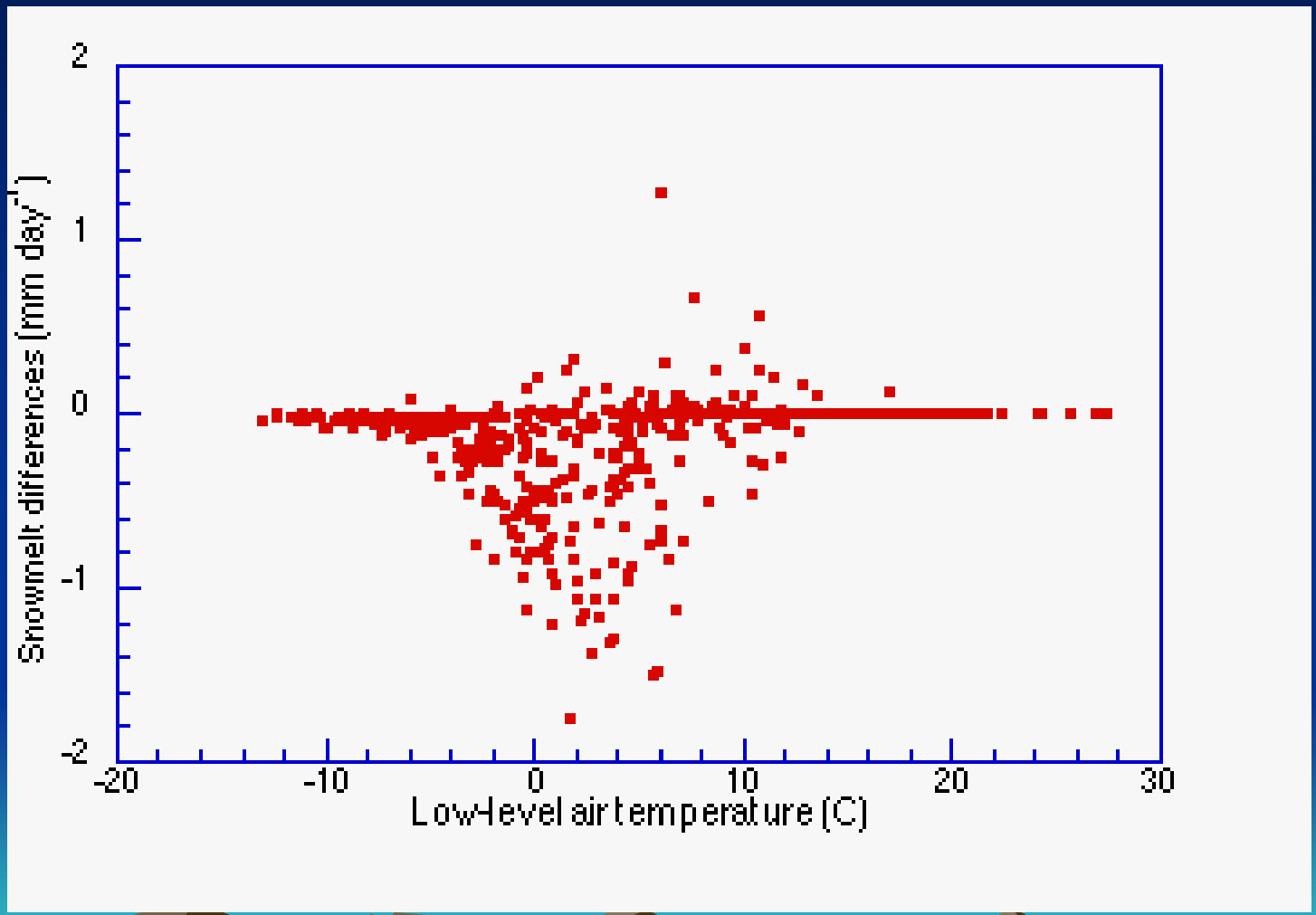
Cumulative Snowmelt (mm) and the 10 m Temp (C)



δInsolation vs. δSnowmelt



δ*Snowmelt* vs. 10 m Air Temperature



Summary: The impact of the direct aerosol radiative forcing on surface insolation and spring snowmelt

- The impact of the direct aerosol radiative forcing on insolation changes is smaller in higher elevation regions as the amount/frequency of clouds increases with increasing height.

- Clouds can effectively mask the impact of aerosol radiative forcing.
  - Need to include indirect effects for quantitative estimation of the impact of aerosol radiative forcing on surface insolation and energy/water cycle.

- Notable impact of the direct aerosol radiative forcing on snowmelt and snowpack occurs only in high elevation regions [> 2000 m ASL].

- The elevation dependence of the impact of aerosol radiative forcing on snowmelt (and snowpack) is strongly related to the low-level temperature variations associated with large elevation changes [the terrain height varies from the sea level to over 3500 m within the region].
  - The amount of snowmelt changes [*due to aerosol radiative forcing*] are not closely correlated with the amount of insolation changes.
  - The amount of snowmelt changes is largest when the low-level temperatures are between -3 C and 5 C.

Summary: Project progress

- Task 1: Build the Integrated Regional Forecast System for southern California to improve the operational flash flood and fire-weather forecasts at the NWSO LA/Oxnard and the VCWPD.
  - Progress so far:
    - The regional forecast system *has been constructed* based on the NCEP WS-Eta model, NWS-AWIPS, and the VCWPD streamflow forecast model and has been integrated within the operational environments at the NWSO and VCWPD.
    - The regional forecast system *is under operational evaluation* as a joint effort between NWSO-LA/Oxnard, VCWPD, UCLA, and JPL.
- Task 2: Examine the impact of GPS-PWV measurements for improving short-term flash flood and fire-weather forecasts in Southern California.
  - Progress so far:
    - The PWV retrieval from the SCIGN array has been established and tested.
    - We have performed case studies to examine the impact of the GPS-PWV data on the regional QPF in southern California. In the February 1998 storm case, use of the GPS-PWV from SCIGN in conjunction with operational Eta forecast improve QPFs in the Santa Barbara and northern Ventura County regions over those based solely on the operational Eta model data.
    - Multiple case studies are underway to examine statistical evaluation of the impact of the additional GPS-PWV from SCIGN on southern California QPF.

Summary: Continued

- Task 3: Seasonal hydroclimate studies
- 3.1 The impact of the GoC SSTs on the warm season water cycle in the SWUS *for improving warm season water cycle forecasts in the SWUS region*.
  - Progress so far:
    - We have completed an experiment comparing the results from two sets of multi-summer simulations driven by the identical large-scale forcing and SSTs except the SSTs in Gulf of California.
    - The results suggest that the GoC SSTs influence the water cycle in the SWUS and NWM via low-level mesoscale circulation and the associated water vapor fluxes. Hence, accurate GoC SST data from remote sensing (e.g., SSMI) are crucial for improving warm season water cycle forecasts in the SWUS region.
    - A paper has been submitted based on this study and is under review process.
- 3.2 The impact of the direct atmospheric aerosol forcing on spring snowmelt in California *for improving seasonal water resources assessments for California*.
  - Progress so far:
    - A spring season fine-resolution simulation has been completed and analyzed.
    - The direct aerosol radiative forcing has notable impact in high elevation regions.
    - Model improvement to incorporate the indirect aerosol effects is needed for quantitative evaluation of the aerosol impact on regional water cycle.
    - A conference paper has been presented at the Fall 2004 AGU meeting in San Francisco. A journal paper is under preparation.

Publications and presentations supported by the project

- Kim, J., J. Kim, J.D. Farrara, and J.O. Roads, 2004: The effects of the Gulf of California SSTs on warm-season rainfall in the southwestern United States and the northwestern Mexico: A regional model study. *Journal of Climate*, submitted.
- Kim, J., Y. Gu and K.-N. Liou, 2004: Elevation dependence of the direct aerosol radiative forcing on surface insolation and spring snowmelt in the southern Sierra Nevada. AGU annual meeting, 13-17 December 2004, San Francisco, CA, A52A-06.
- Marcus, S. L., J. Kim, T. M. Chin, J. O. Dickey, D. Danielson, C. Jacobson and J. Laber, 2004: A regional NWP system for southern California: Applications of GPS-derived PWV retrieval. AGU annual meeting, 13-17 December 2004, San Francisco, CA, A53A-0853
- Kim, J., 2005: A projection of the effects of the climate change induced by increased CO2 on extreme hydrologic events in the western U.S. *Climatic Change*, **68**, 153-168.
- Kim, J., Y. Gu and K.-N. Liou, 2005: Elevation dependence of the direct aerosol radiative forcing on surface insolation and spring snowmelt in the southern Sierra Nevada. in preparation.